

**AN INVESTIGATION OF BUILDING  
INFORMATION MODELLING  
IMPLEMENTATION IN KSA**

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# **AN INVESTIGATION OF BUILDING INFORMATION MODELLING IMPLEMENTATION IN KSA**

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A thesis submitted in partial fulfilment of the requirements of the University of  
Wolverhampton for the degree of Doctor of Philosophy (PhD)

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## ABSTRACT

Building Information Modelling (BIM) has been well recognised all around the world as a technology driven approach that can bring radical improvements in construction productivity. There is considerable demand for using BIM in the KSA due to the large scale of its construction industry that needs to improve its productivity to overcome the persistent problems, such as project delays, planning inefficiencies, and waste of resources. The aim of this study is to investigate how the KSA construction organisations are implementing BIM for competitive advantage. Qualitative research approach was adopted to collect and analyse data from 46 BIM professionals. As part of the analysis of the interviews, content analysis was employed. The unit of analysis adopted for this study is the ‘construction industry’ and the embedded unit is ‘individual employee’.

The KSA construction industry is heading in the right direction for implementing BIM, however it is lacking BIM knowledge and does not understand BIM as a set of requirements. Therefore, an industry wide awareness-raising programme on the concept of BIM needs to be developed and deployed. The existing education and training programmes need some reorientation. Furthermore, the KSA construction organisations would not survive if they choose not to use BIM. BIM is widely used during planning and design stage. The four most important drivers for BIM implementation are: client pressure, competitive pressure, to improve collaboration, and government pressure. Eleven challenges were also revealed in this study of which organisational culture for change is the key challenge for adoption of BIM in the KSA construction organisations. Leaders of a change process need to realise that most changes within an organisation will usually cause and expect some change in its existing culture and sub-cultures. Therefore, having a better understanding of the effects change has on the sub-cultures of an organisation, group or team, will in turn help leaders of a change process better understand the resistance towards the change itself, and provide a more realistic approach on how to manage it. A BIM implementation framework is developed for the benefit of KSA construction organisations. It is recommended that KSA construction stakeholders including the government and professional regulatory bodies should work together in ensuring that the enablers of BIM adoption such as the provision of regulations and industry standards guiding the implementation are provided and strengthened to make the industry ready enough for BIM adoption.

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## **DEDICATION**

This PhD thesis is dedicated to my father Eng. Abdulrahman Al Naim who planted the love of engineering into me since my early childhood and then nurtured this love through practice and experience in his own establishments.

# **CHAPTER 1 : AN INTRODUCTION TO THE STUDY**

This opening chapter introduces this research and set out its background, justification and provides an overview of the research process. This chapter presents the background of this research, demonstrating the need to investigate implementation of latest technology solutions, such as Building Information Modelling (BIM), especially in the context of construction industry in the Kingdom of Saudi Arabia (KSA). The chapter also describes the problem to be investigated, stating the research aim and objectives. The chapter also briefly discusses the researcher's motivation for this research and scope of this study. Finally, the chapter presents an outline of the research methodology and proposed research structure.

## **1.1 BACKGROUND OF THE RESEARCH**

This research is investigating impact of Building Information Modelling (BIM) in the context of construction industry in the Kingdom of Saudi Arabia (KSA). BIM has been recognized, globally, as a technology driven process producing a digital representation of construction projects that has revolutionized the way construction projects are designed, delivered and managed, (Santos, Costa, and Grilob, 2017; Eastman et al., 2008; Underwood & Isikdag, 2009). A number of studies have shown BIM benefits, benchmarking the BIM adoption in various parts of the world, (Aranda-Mena, et al., 2009; Loh et al., 2009; Love et al., 2014). BIM adoption has been significantly increased in recent years after mandatory BIM requirements imposed by the governments and large clients in different countries. For example, the UK government will require BIM on all public sector projects by 2016, (Cabinet Office, 2011), which has pushed the UK construction industry to adopt BIM. Similar initiatives have been

taken in USA, Singapore, Finland, Denmark, and more recently by the EU parliament to promote BIM adoption within their respective markets, (Azhar, Khalfan, and Maqsood, 2012; CIOB, 2014).

The Kingdom of Saudi Arabia as other Cooperation Council for the Arab States of the Gulf (GCC) countries, are experiencing a boom in the construction industries due to heavy investments from governments in infrastructure, housing and commercial development projects, (Albogamy, Scott, and Dawood, 2013; Ali, Al-Sulaihi, and Al-Gahtani, 2013; Kamco, 2011; Surf and Saied, 2014; Turley, 2011). The proven benefits of BIM and a growing global trend for implementing BIM have also influenced the GCC construction market, creating significant growth and trend towards BIM adoption, especially in the UAE and KSA. Dubai municipality has become the first government body in the GCC to impose BIM requirements, (John, 2014), whereas Qatar has shown commitment to apply BIM practices towards all of upcoming FIFA world cup 2022 construction projects, (Gomez, 2013). The first notable BIM initiative in KSA was taken on the construction of King Abdullah University of Science and Technology in 2007, which is still a landmark project in the region for exceptional demonstration of BIM management and proven benefits of BIM applications, (BuildingSMART-ME, 2011). Since then, KSA government is strongly encouraging the use of BIM in the region, indicates that the BIM capabilities of construction companies will play a vital role in public sector project within the Kingdom.

However, the regional construction industry in the KSA is inexperienced in using BIM and lacks strategic and technical expertise required to manage the change in work practices with BIM implementation. Therefore, the introduction of BIM has shown potential for new opportunities for the construction companies, especially for the

contractors, in terms of cost savings and productivity improvements. However, it has also introduces a new line of fears and concerns in the local construction market related to capacity building to deliver BIM requirements and effective implementation of BIM on the projects. This research is designed to study the BIM implementation practices in KSA construction industry.

## **1.2 RESEARCH MOTIVATION AND JUSTIFICATION**

The KSA construction industry is passing through an extraordinary growth as a result of various government initiatives, where the construction projects have become extensive, complex, fast moving, and highly competitive due to the presence of multinational companies in the region. The KSA construction industry has been continuously criticized for its traditional practices leading to delayed projects, waste in production, unhappy clients, over budgeted projects, poor health and safety merits, and inefficient use of resources, (Albogamy et al., 2013; Ali, Al-Sulaihi, & Al-Gahtani, 2012; Al-Kharashi & Skitmore, 2009; Sidawi & Alsudairi, 2014). Previous studies has emphasized that the project delivery time is a critical factor in the KSA construction industry due to its dependency upon expat labour and technical experts. Project delays has been a major and consistent problem in the KSA construction industry, for which inefficient planning and control, lack of site management, and poor resource management are the key reasons, (Albogamy et al., 2013; Al-Kharashi & Skitmore, 2009). Therefore, it is stressed in literature that the KSA construction industry must adopt modern project management techniques and latest digital techniques that can improve the work practices, and eventually the productivity of the KSA construction industry.

The use of BIM has shown strong potential to revolutionaries the project management practices, especially through the use of 4D modelling techniques for project planning and control, ( Alreshidi et al 2017; Mahalingam, Kashyap, & Mahajan, 2010; Velasco, 2013; Zhang and Hu, 2011). A 4D model is created by linking the intelligent 3D objects, project components and assemblies to a time schedule to create simulations for construction sequences, (Velasco, 2013). Further to that, integration of cost information with 4D model, creating a 5D model, enables the various project participants to visualize the progress of construction activities and its related costs over time, in planned verses actual construction scenarios. Application of 4D and 5D modelling extends the 3D model by adding information about productivity rates, resources, execution costs, and component pricing and budgeting reports for the project execution. Thus, the intelligent 3D, 4D and 5D modelling provide opportunities for leveraged integration of construction information and progressively increase the data richness of Building Information Models, which becomes a rich source of upfront informed decision making thoughtful the life cycle of the project. Therefore, the implementation of 4D and 5D BIM can provide significant improvements in project planning and control practices, leading to waste reduction in production, better use of resources, less re-work, fewer change orders and improved projects.

In summary, this research draws its motivation from the fact that the KSA construction industry is under pressure to improve its practices that cause planning insufficiencies, waste, mistakes, rework and as a result, low productivity and unsatisfactory projects. The research is designed under the rational that the starting point has to be project planning and control processes because these areas account for the overall productivity and efficiency of the project delivery process. The application of BIM can provide

opportunities for better project planning and control, which is needed to be researched and investigated in the particular context of the KSA construction industry.

### **1.3 THE RESEARCH PROBLEM**

The applications of BIM can resolve the inherent problems of the KSA construction industry and can improve the productivity in the project delivery process, as discussed above. But BIM is not a fancy use of technology but a collaborative work process that involved several complexities, both at project level and at organizational level BIM adoption. So, it raises questions related to finance and resource commitments for the companies making a move towards BIM adoption, especially in the markets like KSA which are heavily depended on expats and external technical resources. For example, what would be the cost of implementing BIM; are the benefits worth the investment; what improvements BIM or 4D can make to the traditional practices; where are the practical examples, etc.? Market research reports and researchers around the world are trying to answer these questions. McGraw-Hill Construction (2014) reported that three quarter of all contractors in the survey reported positive productivity improvements and return of investment on implementing BIM and these numbers are getting more favourable with increasing BIM maturity in the industry. But what metrics would measure productivity improvement and ROI? In general, the metrics to measure the productivity improvement and ROI on BIM has been cost reduction, waste reduction, energy efficiency, sustainable design and production, carbon footprint reduction, lesser RFIs, fewer unplanned changes, higher customer satisfaction and less disruption in project process, (Chelson, 2010; McGraw-Hill Construction, 2014; Alreshidi et al 2017). It is noted from the literature that the metrics to measure productivity and return of investment are region specific and it can differ greatly depending upon the

circumstances of a market. For example, energy consumption and carbon footprint reduction are on top of agenda in the UK due to legislations and high energy costs, where these metrics are not important in the KSA construction market because of oil driven economy and cheaper energy costs. There are no studies investigating the particular aspects of productivity improvements with BIM application, reflecting upon local BIM experiences and case studies, in the KSA or even in the GCC.

Therefore, the problem being addressed in this research is the need to investigate BIM applications in the particular context of the KSA construction industry. Addressing this research problem requires studying the implementation of BIM in project planning and control on exemplars in the local construction industry.

#### **1.4 RESEARCH AIM AND OBJECTIVES**

The aim of this study is “to investigate how the KSA construction organisations are implementing BIM for competitive advantage”. In order to achieve this aim, the following specific objectives are set:

1. To critically review and document core concepts, uses and applications of bim in the construction industry within the KSA and internationally.
2. To explore the perception of KSA construction organisations on the concept of BIM.
3. To explore the resilience of the KSA construction organisations in the adoption of BIM.
4. To explore the key use of BIM within the KSA construction organisations.

5. To analyse the specific drivers that have fuelled the need for implementing BIM in the KSA construction organisations.
6. To identify and document key challenges for BIM implementation in the KSA.
7. To develop a framework for the implementation of BIM in the KSA construction project.

## **1.5 THE SCOPE OF THE RESEARCH**

The construction industry is very broad and has many disciplines, sectors and segments, all of which have their own particular characteristics, systems and practices. Moreover, the implementation of BIM has several aspects to deal with, related to projects, organizations, technology, process and people. Therefore, it is unrealistic to cover such a broad range of research subjects and participants in a single study. Following points define the scope of this research:

- Many factors contribute to poor performance of the KSA construction industry. This study is limited to studying construction management related factors that relates to productivity and can be internally controlled by the construction organizations.
- BIM is a vast subject area and its implementation has many aspects, uses and applications. This study will be focused on BIM application on the project planning and control practices.
- Although BIM is advocated to bring improvements throughout the life cycle of construction projects; this study mainly considers construction stage, focusing on productivity improvements through BIM enabled planning and control techniques.
- This research is limited to KSA building projects only.



## **1.6 RESEARCH APPROACH**

Building Information modelling (BIM) is an active field of research and extensive research efforts are being made around the globe to investigate various aspects of the BIM technology, process and implementation. This field is advancing rapidly. The research on BIM in the particular context of the KSA construction industry is relatively a new area. Previous research efforts in the KSA construction industry have been focused either criticizing the existing work practices or emphasizing the use of information communication technologies (ICT) to improve the project management in the KSA, (Sidawi & Al-Sudairi, 2014; Sidawi, 2012). These studies are descriptive and exploratory in nature and do not account for applications of ICT in real world projects in the KSA construction industry.

There is need to learn from successful examples of BIM applications in other countries, such as from the UK, USA, Singapore etc, but the actual business case and reality of BIM application can only be established by studying the BIM implementation in the KSA construction industry. Therefore, this research uses qualitative study to develop a deeper understanding of the subject, (Rossman & Wilson, 1991; Yin, 2008).

## **1.7 OUTLINE OF THE RESEARCH METHODOLOGY**

The term research methodology is used to describe the overall research process including the theoretical underpinning, collection and analysis of the required data, (Graziano and Raulin, 2012). Considering the nature and objectives of this research, the research process is divided into three stages, which are identifying the research gap,

data collection and analysis and development of the framework. These stages are briefly explained in the following sub sections.

- Identifying the research gap: This stage includes a comprehensive literature review on the related research topics. A literature review is the first step in any research investigation which provides a fresh review of subject, an analysis of earlier writing in order to identify the knowledge gap (Ruane, 2011). Keeping in view the context of this research, the literature review will cover the key topics related to BIM applications, which will establish the context of this research. The literature review will also provide insights into BIM adoption in the UK, USA and other developed countries to learn from the example in order to study the BIM adoption in the KSA. In summary, the literature review will identify the research gaps and will provide the foundation to carry out further research investigations. The outcomes of this stage will be a clear understand and documentation of the research area and the research problem under investigation.
- Data collection and analysis: In this stage, organisations are selected to collect the primary research data. These organisations might have completed or on-going projects in which BIM is been used. Collected data will be analysed using content analysis.
- Development of framework: The research results from the previous stage will be used to develop a framework.

## **1.8 CONTRIBUTION TO KNOWLEDGE**

This research has contributed to knowledge in the following ways:

- The research investigated the understanding of BIM along with the drivers, uses and challenges. This research study contributes to the body of knowledge by serving as an exploratory study investigating how organisations are likely to react to implementing BIM in KSA construction organisations with regards to the drivers, uses and challenges.
- This study also developed a framework showing a roadmap for implementing BIM in the construction industry in KSA. This framework has four phases. It starts with when to implement BIM, are there any government mandates and to determine BIM use with decisions and options provided for the users. This research provides a starting point for facilitating and implementing BIM through the developed framework.

## **1.9 RESEARCH STRUCTURE**

The structure of this research is explained reflecting on the research stages, research methods adopted and division of the thesis chapters.

Chapter 1 provides general introduction to this research, discusses the research background, research motivation and justification. This chapter also states the research aim and objectives. The details of the thesis structure are also provided.

Chapter 2 reviews the literature on general BIM concepts. This chapter introduces various aspects of BIM and its implementation at organizational, process and product levels. It discusses various methods which are proposed and used to increase productivity in construction and lead the discussion into present state of BIM. This chapter also discusses performance benefits and barriers with BIM adoption.

Chapter 3 presents a review of BIM adoption efforts all around the globe. Initially, this chapter discusses BIM adoption in developed countries which are leading in BIM (e.g. USA, Scandinavia, UK etc) reflecting that BIM adoption in these countries is a policy initiative and strongly supported by their governments and professional institutes. Then, the chapter discusses BIM adoption in emerging markets for BIM, including KSA, to give an up to date perspective on BIM adoption. The situation of the KSA construction industry, typical characteristics of the KSA, existing problems and scope for BIM implementation within the markets are also reviewed.

Chapter 4 presents the detailed research methodology including the research philosophy, approach and methods adopted. It explains how qualitative methodology was used to collect primary data in KSA. Furthermore, it discusses content analysis.

Chapter 5 presents the comprehensive data analysis and research results on the perception of KSA on the concept of BIM is and the uses of BIM. It also explains the role of BIM during planning and design stage, construction stage and post-construction.

Chapter 6 and chapter 7 discuss the results with respects to drivers and challenges for the implementation of BIM in the KSA construction organisation. Also, the developed framework is incorporated in chapter 7.

Chapter 8 evaluates and concludes the research. A reflection on research aim and objectives is presented. Original contribution to knowledge and future research directions are provided.

## **CHAPTER 2 : A REVIEW OF LITERATURE ON BUILDING INFORMATION MODELLING**

### **2.1 INTRODUCTION**

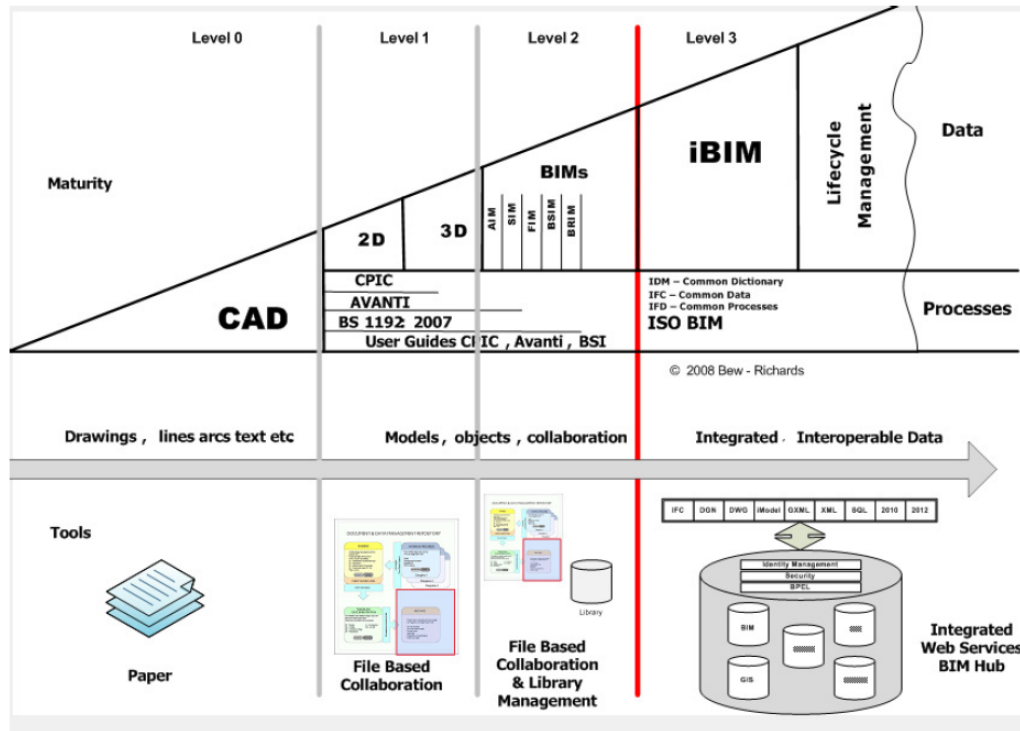
This chapter is focused on general understanding of BIM and its core concepts with regards to the application. Then it draws out literature specifically on productivity in the construction industry and potential for productivity improvements with application of BIM. This is because the construction industry is criticised for its low productivity, largely because of non-collaborative work practices leading to poor planning and waste in design and production processes. This chapter presents the background of BIM leading to its current and future status of development, BIM advantages over traditional CAD, BIM definitions, BIM uses and existing BIM tools and software applications. This chapter also briefly discusses BIM implementation challenges in terms of organisational BIM adoption, highlighting process and technical BIM implementation challenges. This chapter has introduced BIM as a solution; a technology-led-process that can bring numerous benefits to the construction industry.

### **2.2 BACKGROUND OF BUILDING INFORMATION MODELLING (BIM)**

In general, the construction industry has been criticised for its poor performance and traditional ways of working, which are non-productive, non-collaborative and inefficient (Aouad et al., 2005; Egan, 1998; Howell & Batcheler, 2003; Latham, 1994). Many researchers have highlighted that the ineffective procedures in the traditional construction practices are due to the fragmentation of the construction industry, lack of trust among parties, poor information coordination, adverse contractual settings and lack of customer focus in the construction production process (Cooper et al., 2005;

Ashcraft, 2008; Aouad & Arayici, 2010). A key reason for the low performance of the construction industry is poor coordination and inconsistency in the way that multi-disciplinary practices manage and exchange project information. For the last two decades, the construction professionals have been involved in adopting new technologies and innovative ways to manage coordination and information exchange challenges. Building Information Modelling (BIM) is one such technology driven approach which has shown strong potential to bring significant productivity improvement in the construction industry (Bernstein and Pittman, 2004; McGraw-Hill Construction, 2014; Saini & Mhaske, 2013; Succar, 2008; Yan and Damian, 2009). The numerous benefits of BIM have been reported by several research project and case studies which cluster around better design, better visualization, better communication and better management of the construction projects from early design to facility management (Ashcraft, 2008; Becerik-Gerber & Rice, 2010; Love et al., 2014; Manning and Messner, 2008; Poerschke et al., 2010; Saini & Mhaske, 2013).

The term BIM became popular after 2002 (Laiserin, 2009) and its adoption in the industry was accelerated due to software vendor's marketing and increasing interest of Governments and client organisations to achieve productivity improvement targets with BIM implementation (AGC, 2006; Autodesk, 2002; NIBS, 2007). However, the concept of BIM and underlying technology is not new and has been an area of research and development in last three decades, mostly known as product modelling for buildings, (Eastman and Augenbroe, 1998; Kiviniemi, 2006). Today, the construction industry is experiencing a gradual shift from paper based 2D CAD drawings to object oriented 3D digital models which is driven by the application of BIM, as reflected in Bew-Richard's BIM maturity model in Figure 2.1.



**Figure 2.1: Bew-Richard's BIM maturity model**

*Source: (PAS 1192-2, 2013)*

A BIM maturity level determines the degree of efficiency in implementing the technology and process to collaborate the building information in a project environment. Level 0 BIM maturity reflects unmanaged CAD in 2D that is represented and exchanged in paper documents (including electronic documents). Level 1 explains a managed CAD environment using 2D and 3D representations of the building information. Information content at level 1 is created by using standardised approaches to data structures (CAD standards), and stored in standard formats that can be exchanged among different CAD applications. Level 2 maturity represents a managed BIM environment that contains intelligent BIM models held in separate disciplines (discipline models), shared and coordinated using a structured approach on a CDE and integrated using proprietary or bespoke middleware software for design (e.g. Architectural structural etc.), analysis (e.g. Energy analysis, clash detection), project



management (e.g. 4D, 5D) and maintenance purposes (PAS 1192-2, 2013). Level 3 BIM represents fully integrated and collaborative BIM enabled by web services to collaborative building information using open standards without interoperability issues and extending BIM applications towards lifecycle management of building projects.

The next section will discuss various BIM definitions exploring BIM concepts in more details.

### **2.3 UNDERSTANDING BIM: DEFINITIONS AND CONCEPTS**

The literature review revealed that BIM has been defined in a number of ways and its understanding varies among the industry professionals. BIM is defined and presented as technology, or a process or a combination of both in a new methodology to trigger a paradigm shift in the working of the construction industry. According to Autodesk, (2002), a Building Information Model is basically a 3D representation of physical and functional characteristics of a building throughout its life cycle. For example, in a Building Information Model a window of certain material and dimension is digitally hosted in a wall of certain material and dimensions under parametric rules. Any change in building components is instantly coordinated to all associated view of the digital model which can be used as knowledge recourse to extract various views, reports, and reliable data for functional analysis of the building, (Autodesk, 2002).

A different view of BIM is presented by AGC (2006) in which BIM is defined as the development of use of technology to digitally simulate the design, construction and operation of a facility from where different views of data appropriate for various users can be extracted and used for decision making that can improve the process of overall project delivery. Another formal definition of BIM is presented by NIBS (2007) as

“Building Information Model is a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle”.

Eastman et al. (2008) stated that a Building Information Model is constructed from intelligent digital assembly of building components with embedded knowledge of parametric object attributes and characteristic. Kymmell (2008) has explained BIM as a tool or process or product that can generate intelligent digital models connected with other project management tools (e.g. schedule, BOQ, cost estimate) that facilitate design optimization, constructability, and information collaboration for all stakeholders for a better project output. The process view of BIM is supported by a large number of authors who declare BIM as a lot more than just a technology for digital representation of buildings.

Succar (2009) has called BIM as a set of interacting policies, process and technologies producing a new methodology to manage the design, construction and operations of construction projects through their life cycle. According to Gu & London, (2010) BIM is an IT enabled approach to manage digital information in the construction industry. More recently Aouad & Arayici, (2010) stated that the BIM is the use of all related information communication technologies (ICT) which are needed to streamline and facilitate all the processes which are involved in creation of a safer and a better environment. Most recent authors as called BIM a technology driven process to create information rich, intelligent models, which support life cycle information management for built environment projects, (Hedges & Beach, 2012; Lee, Kim, & Yu, 2014; Love et al., 2014; Saini & Mhaske, 2013).

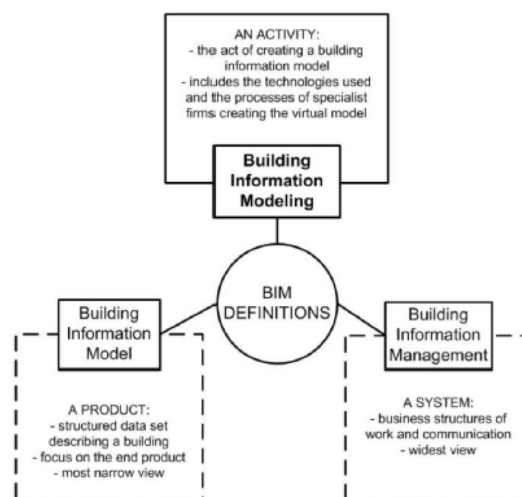
An analysis of BIM definition suggests that the “BIM as a technology” view is supported by software vendors which are producing the technology and softwares for BIM implementation in the industry. Whereas “BIM is a process or activity” view is backed by professional institutes in the industry which are main drivers for reengineering the industry practices to incorporate and support BIM enabled working. And “BIM as a system, as a holistic approach and collaboration methodology” is described by academics working in research and development of BIM theory and adoption in the industry. Some examples of these views are presented in the Table 2.1.

**Table 2.1: Different perspectives on BIM definitions from literature review**

<b>BIM definitions by product vendors, industry and academia</b>		
Product vendors	Asta Power Project (2018)	The Industry Foundation Classes (IFC) data model is an open, international and standardised specification for Building Information Modelling (BIM) data that is exchanged and shared among software applications used by the various participants in a building, construction or facilities management project.
	Autodesk (2002, 2014)	BIM is use of information technology
	Graphisoft (2014)	BIM is a technology that offers users simulation, collaboration, auditability and maintainability.
	Bentley & Workman, (2003) and Bentley, 2011)	BIM is a new way of approaching the design and documenting of building projects
Professional institutes and the industry	VVT Finland (Bazjanac & Kiviniemi, 2007)	BIM is strategic thinking, tactical thinking and operational thinking supported by the use of technology.
	AGC (2006)	BIM is an activity of creating data-rich, object oriented, smart and parametric digital representation of a facility.
	NIBS (2007)	BIM is an entity with multiple features: it is a product, a process and a system to design, deliver and operate built assets.
	BuildingSMART (2014)	BIM is a process to create digital representation of physical and functional characteristics of a facility.

BIM academics	Poerschke et al., (2010)	BIM is collaboration process by different stakeholders at different phases of the life cycle of a facility.
	Succar (2009)	BIM is a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and operations of construction projects thought their life cycle.
	Azhar (2008)	A BIM model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule.
	Hardin (2009)	BIM as a process of adopting and establishing a new notion of thinking.
	Eastman at al., (2008)	BIM is not just a technology but a process, as vast as a multi-disciplinary design, analysis, construction and facility management technology, as well as the harbinger of dramatic process change.
	Abanda et al (2015)	BIM is a collaborative software that is used at different stages of construction.
	Santos, Costa and Grillo (2017)	Modelling building information based on multiple aspects (e.g. spatial design, building structure, and energy)

It can be concluded from the above definitions that BIM has been presented as a product (BIM model), an activity (process) to create a product and a system to manage the activity and product, as represented in the Figure 2.2.



**Figure 2.2: Various perspectives on BIM definitions**

*Source: (Chelson, 2010)*

For the purpose of this research, BIM is considered as a collaborative process and methodology supported by the use of ICT to manage the essential building design, production and maintenance information through a project life cycle.

### **2.3.1 BIM VURSES TRADITIONAL CAD**

The construction industry is practicing Computer Aided Design (CAD) using a number of tools since decades which are capable of producing good project representations in term of drawings, documents and even interactive 3D models. Therefore, the less-informed construction companies are hesitant to accept BIM, wondering the difference in BIM 3D models and traditional 2D/3D CAD models (Steel, Drogemuller, & Toth, 2010), which is a factor for slow uptake of BIM in the construction industry, especially in developing construction markets such as KSA (Baldwin, 2013; BuildingSMART-ME, 2011).

It is identified from the literature that the key difference in traditional CAD and BIM is the object oriented nature of BIM models (Eastman et al., 2010; Kymmell, 2008) which enables intelligent connections and information manipulation, making BIM models more powerful and useful as compared to CAD models. The traditional CAD models (2D & 3D) are created using drawing tools which do not have the object oriented intelligence, for example Stekch up, AutoCAD, Rhino, 3D StudioMAX etc. Traditional CAD 2D drawings and 3D models have no physical/computing relationship other than their interpretation as counter parts representing elevations, sections, plans and 3D views of a design. So, the 2D/3D CAD model only gives representation of lines, arches, 3D elements which only make sense with human interpretation and no automated computing applications are possible in design, analysis and management of

CAD drawings and models (Babič, et al., 2010; Bazjanac & Kiviniemi, 2007). As a project moves from concept to design, construction and handover, the information in CAD drawings and CAD 3D models becomes outdated and cannot be updated to represent the progression of the design intent, construction production or facility management operations.

On the other hand, BIM models are intelligent and still can be used to create 2D drawings, documents and 3D views at any point with minimum effort and which are all synchronized and represent a complete design or information rational. Therefore BIM is both 2D and 3D but BIM tool can create model that can produce far more information. Eastman et al., (2008) explained that following 3D models cannot be classified as BIM models, if

- Models contain 3D data only but cannot provide or support data integration and analysis.
- Define objects but cannot support the behavior such as adjust the positions and relationships of components.
- Models are composed of 2D CAD files, the 3D models result of these combinations cannot be ensure to be respect to the original objects.
- The models allow changes to dimensions in one view but cannot in others.

A true BIM tool has an integrated database where the data is the project model and the reports of the database are the queries or views of that model (Gu et al., 2009). Therefore, all plan views, section views, elevations, callouts, perspectives; even schedules are live within a single project model. Construction projects and project teams work in discipline silos (architect, contractor, engineers) which are separate entities, and function independently at each stage of a project (Anumba & Newnham,

2002; Anumba et al., 2008). So, when a project progress from concept design to further development, the information in traditional CAD models is transferred using an “over the wall” practice because CAD information cannot be integrated to create a single point of truth and hence restrict collaboration among project participants. Also, this practice leads to unlimited number of documents, drawings, drawing versions and change histories which are difficult to manage and maintain separately. These results in problematic communication and coordination of information, process bottlenecks, errors, duplicate information, and often conflicts leading to legal proceedings (Anumba et al., 2008; Cooper et al., 2005). So, the overall process with CAD models is unstructured, error prone, non-collaborative and inefficient. In contrast, BIM workflows are built around the concept of integration and collaboration creating a single point of truth for all the project information in intelligent information repository. BIM models allow the project teams to visualize and resolve the design problems throughout the work process using concurrent and parallel work streams. BIM models significantly reduce design error and greatly improve the quality required by multiple 2D documents, leading to fewer changes during construction (Azhar et al., 2012; Bryde, Broquetas, & Volm, 2013).

In summary, traditional CAD practices use technology in isolation but BIM processes use technology to support collaborative working. Jernigan (2008) stated that the “I” in BIM acronym is information, that is where the opportunities exist and that is where the value is too for project success. BIM is a technology led process, without the fit for purpose technology it cannot work and without the efficient processes, the BIM technology has only limited value.

### 2.3.2 BIM DIMENSIONS

A basic Building Information Model is an object oriented 3D model which has various applications and uses in different project stages but it is not limited to that, it can be a 4D, 5D or nD model (Aouad et al., 2005) extending the BIM applications throughout the project life cycle. These are called BIM dimensions in literature (AGC, 2006), and are briefly explained in the following points.

- 2D BIM: BIM model is 3D but it can be used to generate 2D drawings and documents (Autodesk, 2002).
- 3D BIM: Object oriented 3D geometric models with imbedded intelligence, semantic, functional and performance information which can be used for visualization, navigation, clash detection, design interrogation etc, (Autodesk, 2002; Azhar et al., 2012; Nederveen et al., 2010).
- 4D BIM: Associating time (Schedule) with geometry turn a 3D BIM model into a 4D mode that can be used to simulate production assembly and progress monitoring, (Turkan et al., 2012; Zhou et al., 2013).
- 5D BIM: Adding cost and budget information to a 4D BIM model is called 5D modelling, creating a 5D BIM model for automated estimation and cost management (Mitchell, 2012; Popov et al., 2010).
- 6D BIM: 6D BIM model contains procurement, supply chain information and production information. An as built model or FM model is also called a 6D model, (Hardin, 2009).
- 7D BIM: Integration of sustainability components and related information in a BIM model makes it a 7D model (Nederveen et al., 2010).

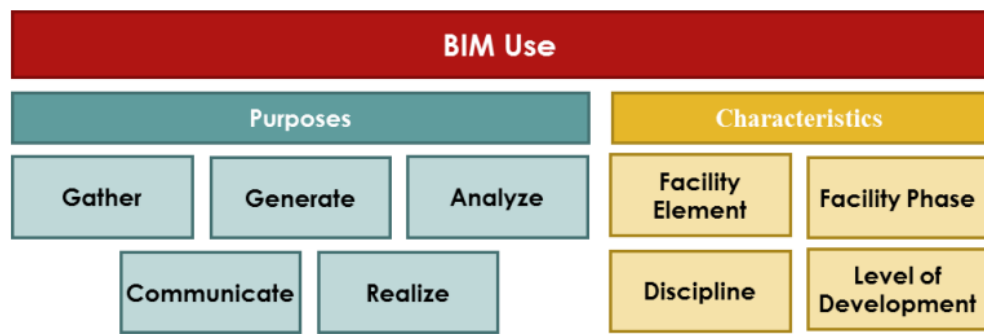


- nD BIM: An nD BIM model is theoretical and indicates that the applications of BIM model are numerous and can achieve any number of dimensions in future (Aouad et al., 2005 and Fu et al., 2006).

6D & 7D BIM are not yet clear and therefore their definitions are often overlapped or confused. This study is limited to investigate BIM uses and applications up to 5D models, mainly focusing on BIM applications in construction planning and production which is achieved with 4D models. Therefore, this study will limit itself to exploring 3D, 4D and 5D aspects of BIM and their application and impact on productivity, with a focus on 4D, in the later sections.

### **2.3.3 BIM USES AND BENEFITS**

A fully coordinated and functional BIM model can be used for a number of applications in the all phases of a project life cycle. It is important to note that the BIM uses and applications depend on the nature of project, work environment and technical maturity of project participants. However, the overall objective of BIM use remains same which is to create a shared pool of data to increase collaboration among all project stakeholders, and as a result, achieve better productivity. According to Kreider & Messner (2013) a BIM use is “a method of applying Building Information Modeling during a facility’s lifecycle to achieve one or more specific objectives.”. These authors have presented a classification for BIM uses based on the purpose for implementing BIM through the life cycle of building projects, which is reflected in the following Figure 2.3.



**Figure 2.3: Components of BIM uses**

*Source: (Kreider & Messner, 2013)*

Based on the components of BIM uses, as represented in Figure 2.3, a number of BIM uses are identified from the literature, for example design review, visualization, 3D Coordination, design authoring existing conditions modelling, phase planning, record modelling, site analysis, code validation and asset management. For more detailed description of BIM uses and their relationship with purpose in project implementation, please refer to Kreider & Messner, (2013). Although the construction industry is still going through the transition process to shift its practices to BIM enabled workflows, yet significant benefits of BIM are reported all around as compared to the traditional approach that have already been realized. Some of key BIM benefits are explained in the following sub-section.

#### ▪ **BIM IN THE DESIGN PHASE**

BIM is used in producing schematics design details and improving the presentation of projects to clients for easier and better decision making, and for a clearer understanding of the nature or scope of work to be conducted. Autodesk (2002) stated that BIM is used for the detailed analysis of energy and efficiency, sustainability, cost estimates,

schedule and budget information of buildings, (Azhar et al., 2009; Barlish & Sullivan, 2012; Bryde, Broquetas, & Volm, 2013). BIM is also used in the analysis of building services which could help with clash detections (Hardin, 2009). Timely choices and changes made during the design scope and scheduling can affect the cost and time of construction. However, through the use of BIM tools, these changes can be achieved simply, readily and accurately, reducing the time and costs of project. Olofsson (2003) also highlighted a few benefits from case studies on BIM implementation in healthcare projects at the conceptual stages which include: quick visualisation; good decision shore up in project development process; precise automatic updating; diminution of man hours for space programs; increased project team communication; and increased confidence of scope of work.

#### ▪ **BIM IN PRE-CONSTRUCTION AND CONSTRUCTION PHASE**

The construction process follows the design phase in a traditional procurement method while in a D&B method they are conducted side by side. The construction stage involves more professionals compared to the design phase. Additionally, sub-contractors such as mechanical, electrical and plumbing (MEP) participate. Autodesk (2002) stated that the use of BIM in the construction phase enables scheduling and work flow coordination, while at the preliminary preconstruction level; it includes cost estimates, virtual construction logistics of cranes and materials on site. The key benefits of the construction phase identified are:

1. The targets and scheduling of construction schemes
2. Scheduling what is constructible
3. Clash detection and reporting; and

4. Quality of projects has been analysed and improved by rescheduling projects to improve value.

The 4th Dimension is of particular importance as BIM is used in the construction phase to establish and evaluate various construction options, (Velasco, 2013). It is been developed by comprehending schedule dates from project plan to model, the evaluation of construction sequence, detection of clashes, identifying construction milestones, understanding and relating the project to owner and contractor can be done more easily using 4D modelling. A 4D model can be obtained by adding schedule data to a 3D building design, introducing time as the 4th dimension.

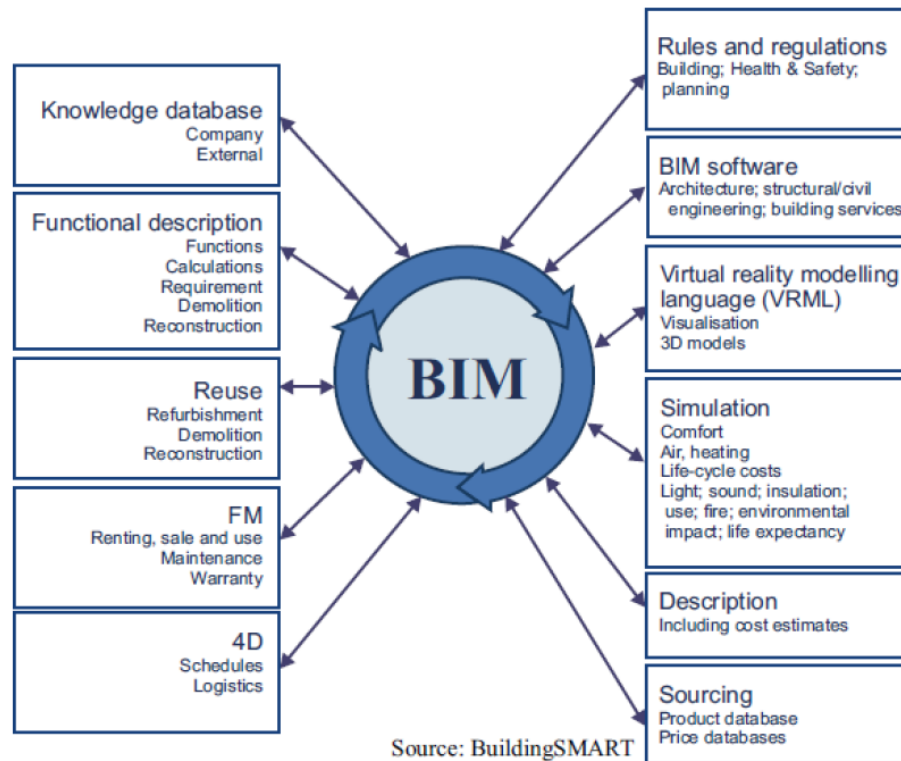
#### ▪ **BIM FOR FACILITY MANAGEMENT**

Hardin (2009) and Eastman et al. (2008) agree that BIM is used in the operational analysis of a facility within a BIM environment. Anumba et al. (2008) state that the application of BIM is extended above the design and construction phase which goes into facility management for the purpose of maintenance and maximizing the value of a facility. Gu et al., (2009) described that facility managers will need to maintain an accurate inventory of space. They also stated that Computer-Aided Facility Management (CAFM) and the International Facility Management Association (IFMA) categorized facility management functional responsibilities into:

- Long-range and annual facility planning
- Facility financial forecasting
- Work specifications, installation and space management
- Real estate acquisition and / disposal
- Architectural and engineering planning and design

- New construction and / renovation
- Maintenance and operational management; and
- Telecommunication integration, security, and general administrative services.

A summary of the key BIM uses and functions is reflected in figure 2.4



**Figure 2.4: Summary of the key BIM uses**

*Source: (BuildingSMART 2010 cited in Dung & Tarar, 2012)*

It is important to note that BIM benefits and productivity improvements are dependent on BIM uses, maturity level of organisations and effective implementation on projects. Based on these prerequisites, Jernigan (2007) presented two distinctions of what is known as Big BIM and little BIM. Little BIM limited use of BIM technology for shallow gains, whereas the Big BIM is the collaborative BIM with all-encompassing process that is widely published and advocated to change the construction industry.

## **2.4 BIM TOOLS AND SOFTWARE APPLICATIONS**

BIM has offered a new range of software tools and applications which can be used to create analyse and manage BIM models in all phases of a project life cycle. A key characteristic of BIM software tools is storing information in BIM model databases which remain there until modified or deleted, making information evolve from schematic to detailed design and beyond. Another crucial aspect of BIM tools is the ability to exchange information without software tools and applications, known as interpretability, which is the key to effective collaboration within the project team. BIM software tools and applications can use their native formats, proprietary data formats, to exchange information between similar software family tools or exchange information in a neutral data format, for example using Industry Foundation Classes (IFC) format, among heterogeneous software platforms.

The construction industry users have to rely on software vendors and developers for BIM tools which are suitable for various uses and applications. Since the introduction of CAD, software vendors are driving the development and implementation of new technologies which allow design flexibility as well as computer intelligence to create effective information models, leading to a number of BIM tools and software applications, which are available today for the construction industry. There are literally hundreds of BIM compliant software tools available today and more are emerging with the growing uptake of BIM in the global construction industry. In literature, a number of authors have classified BIM tools into different categories, such as preliminary space planning tools, preliminary massing and sketching tools, preliminary environmental analysis tools, preliminary cost estimation tools, BIM design tools, structural design tools, BIM construction tools, fabrication tools, environmental analysis tools,

construction management tools, cost estimation tools, specification tools and facility management tools. The following table presents an overview of the key BIM tools, uses and applications in different stages of a project's life cycle.

**Table 2.2: Matrix of common BIM tools and applications**

*Source: (BIMForum, 2014)*

PRELIMINARY DESIGN AND FEASIBILITY TOOLS	BIM tools	BIM use	Primary Functions	Vendor
	Revit Architecture	Creating and reviewing 3D models	<ul style="list-style-type: none"> <li>Architectural Modeling and parametric design.</li> </ul>	Autodesk
	DProfiler	Conceptual Design and Cost Estimation	<ul style="list-style-type: none"> <li>3D conceptual modeling with real-time cost estimating</li> </ul>	Beck Technology
	Bentley Architecture	Creating and reviewing 3D models	<ul style="list-style-type: none"> <li>Architectural Modeling</li> </ul>	Bentley Systems
	SketchUp Pro	Conceptual 3D Modeling	<ul style="list-style-type: none"> <li>Conceptual Design Modeling</li> <li>3D Architectural and Structural modeling</li> </ul>	Google
	ArchiCAD	Conceptual 3D Architectural Model	<ul style="list-style-type: none"> <li>Architectural Model Creation</li> </ul>	Graphisoft
	Vectorworks Designer	Conceptual 3D Modeling	<ul style="list-style-type: none"> <li>Architectural Model Creation</li> </ul>	Nemetschek
	Tekla Structures	Conceptual 3D Modeling	<ul style="list-style-type: none"> <li>A structural 3D Model Application</li> </ul>	Tekla
	Affinity	Conceptual 3D Modeling	<ul style="list-style-type: none"> <li>A 3D Model Application for early concept design</li> </ul>	Trelligence
	Vico Office	Conceptual 5D Modeling	<ul style="list-style-type: none"> <li>5D conceptual model which can be used to generate cost and schedule data</li> </ul>	Vico Software

<b>BIM AUTHORING TOOLS</b>	Revit Suite	Multi-disciplinary design	<ul style="list-style-type: none"> <li>Architectural, Structural, Mechanical, Electrical and Generative Components – all within the 3D modeling environment</li> </ul>	Autodesk
	Bentley BIM Suite	Multi-disciplinary design	<ul style="list-style-type: none"> <li>Architectural, Structural, Mechanical, Electrical and Generative Components – all within the 3D modeling environment</li> </ul>	Bentley Systems
	Digital Project	Multi-disciplinary design	<ul style="list-style-type: none"> <li>Digital Project Designer is a high performance 3D modeling tool for architectural design, engineering, and construction.</li> </ul>	Gehry Technologies
	ArchiCAD	Multi-disciplinary design	<ul style="list-style-type: none"> <li>3D Architectural Modeling</li> </ul>	Graphisoft
	Vectorworks	Architecture design	<ul style="list-style-type: none"> <li>3D Architectural Modeling</li> </ul>	Nemetschek
	Tekla Structures	Structural design Site Logistics	<ul style="list-style-type: none"> <li>3D Structural Modeling, Detailing.</li> <li>Fabrication and Construction Management</li> <li>A fully integrated BIM solution based upon a structure-centric approach</li> </ul>	Tekla
<b>BIM ANALYSIS TOOLS</b>	Robot	Structural Analysis	<ul style="list-style-type: none"> <li>Bi-directional link with Autodesk Revit Structure</li> </ul>	Autodesk
	Ecotect	Energy Analysis	<ul style="list-style-type: none"> <li>Weather, energy, water, carbon</li> <li>emission analysis</li> </ul>	Autodesk
	Solibri Model Checker	Model Checking & Validation	<ul style="list-style-type: none"> <li>Rules-based checking for compliance and validation of all objects in the model</li> <li>Spatial Coordination</li> <li>QA/QC of models based upon rule sets and spatial requirements</li> </ul>	Solibri
	Fluent	Air Flow	<ul style="list-style-type: none"> <li>Environmental simulation and analysis</li> </ul>	Ansys



CONSTRUCTION MANAGEMENT	Navisworks Manage	Clash Detection & scheduling	<ul style="list-style-type: none"> <li>Model-based Clash Detection between trades</li> <li>Linking 3D model to popular project schedule applications (e.g. MS Project or Primavera)</li> </ul>	Autodesk
	ProjectWise Navigator	Clash Detection & Scheduling	<ul style="list-style-type: none"> <li>Coordination between models and disciplines</li> </ul>	Bentley Systems
	Vico Office	Coordination	<ul style="list-style-type: none"> <li>Vico Office allows to combine BIMs from multiple sources and can then be coordinated, scheduled and estimated</li> </ul>	Vico Software
	Synchro Professional	Scheduling	<ul style="list-style-type: none"> <li>Bi-directional linking to popular project schedule applications (e.g. MS Project or Primavera)</li> </ul>	Synchro
COLLABORATION	Buzzsaw	File Sharing	<ul style="list-style-type: none"> <li>A repository for all project related</li> </ul>	Autodesk
	Constructware	Collaboration	<ul style="list-style-type: none"> <li>Web-based suite of management tools for construction projects</li> </ul>	Autodesk
	cBIM	Model sharing collaboration	<ul style="list-style-type: none"> <li>Web-based suite of management tools for construction projects</li> </ul>	ASite
	4BIM	Model sharing collaboration	<ul style="list-style-type: none"> <li>Web-based suite of management tools for construction projects</li> </ul>	4Projects
	BIM server	Database level BIM collaboration	<ul style="list-style-type: none"> <li>A server based solution for multi-disciplinary BIM coordination and collaboration.</li> </ul>	BIMserver.org

In addition to these primary software tools and applications, there is a range of other BIM supportive tools, for example 3DVia Space, bonzai3D, FormZ, Trelligence Affinity etc and these are growing fast with the uptake of BIM in the industry. While the BIM technology has become available, the practical implementation of the BIM

process and adoption within the organisation and construction projects is still a challenging task. A fully understanding of all aspects of BIM is never required to see the tangible BIM benefits or productivity improvements as BIM uses are highly customisable and therefore suitable for all type of construction projects, organisations and regions. Even with limitations and challenges of BIM implementation (organisational, project and technology), the incremental value added by BIM is still beneficial and empowering to the construction industry and project teams.

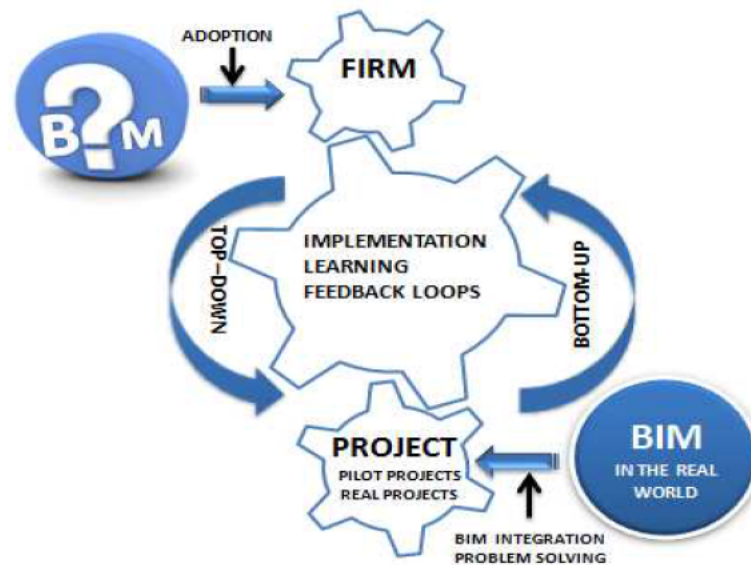
## **2.5 BIM IMPLEMENTATION CHALLENGES**

The benefits of BIM and associated productivity improvements are well acknowledged, which are now becoming more evident as the industry is maturing the uses of technology and processes (Kreider & Messner, 2013; McGraw-Hill Construction, 2014). However, BIM adoption and implementation on real projects is not without challenges which are slowing the BIM uptake in the industry. BIM has been called “disruptive technology” (Eastman, 2008) as it can have a multifaceted effect on existing working practices, procurement strategies, legal and contractual setting, data ownership and security and insurances (Bernstein and Pittman, 2004; Gu and London, 2010; London et al., 2008). Then there are issues related to organisational changes, software and hardware costs, associated training and learning curve, people resistance to change and general fear of change (Aranda-Mena et al., 2009; Arayici et al., 2011; Samuelson & Ab, 2010). A number of authors have discussed the BIM implementation and adoption challenges which are mainly related to (1) organisational level BIM adoption; (2) Process-project level BIM implementation; and (3) technology related BIM challenges.

Organisational level BIM implementation challenges are related to changes in policy, working culture, people and associated costs. The fear of change poses the largest latent barrier to BIM adoption and implementation. It is psychological phenomena that when people are successful in doing something, they feel comfortable in doing the same thing over and over again. Since BIM is bringing multi directional changes in the ways people work and operate, organisations are likely to face resistance from people against the change. Another issue is that organisations are lacking documentation of BIM standards or workflows, no institutionalized quality controls for BIM models and no BIM-specific risk identification or mitigation policies, which are universally endorsed and agreed. Large organisations and insurance companies are still unable to price and write insurance policies for BIM projects, because the historical data is not available as the empirical evidences of BIM productivity improvements is yet being collected.

London, (2008) highlighted that organisational level BIM adoption is dependent upon the relationship between current work practices and future BIM scenario as perceived by the policies of an organisation. For example, if an organisation is currently at zero BIM level (Figure 2.1) and wants to achieve level 2 BIM status in a couple of years, it is going to be a tough target and would need extensive resources, planning and commitment in implementing BIM. So, to what extent BIM can change the current work practice is the key factor in its adoption at an organisational level. It is a common perception that all existing workflows, processes and business model must change if a company want to accept BIM, which is not a correct assumption as BIM can be tailored to suit the requirements and thus the change can be customised. Although some authors have stressed otherwise, such as (Aouad & Arayici, 2010; Arayici & Egbu, 2012), stating that BIM adoption requires significant changes in current business practices at

every level within organisation. A model of BIM innovation and adoption process at an organisational level is presented in the Figure 2.5.



**Figure 2.5: BIM innovation process at organisational level**

*Source: (Dung & Tarar, 2012)*

Process level BIM adoption challenges are related to information transfer bottlenecks, current lack of parametric content for significant project vendor products, unfamiliarity of BIM's breadth of ability and associated experience of application in programming, and a lack of understanding of interoperability limitations and abilities, (Manning and Messner, 2008). Also, Froese (2009) stated that the impact of BIM on current project management practices and processes cannot be realized without corresponding changes in organisations and skill sets of the project participants. Henrik and Linderorth (2010) highlighted the need to redefining project roles in current network of construction projects from top management to bottom line supply chain to suit the BIM process management requirements.

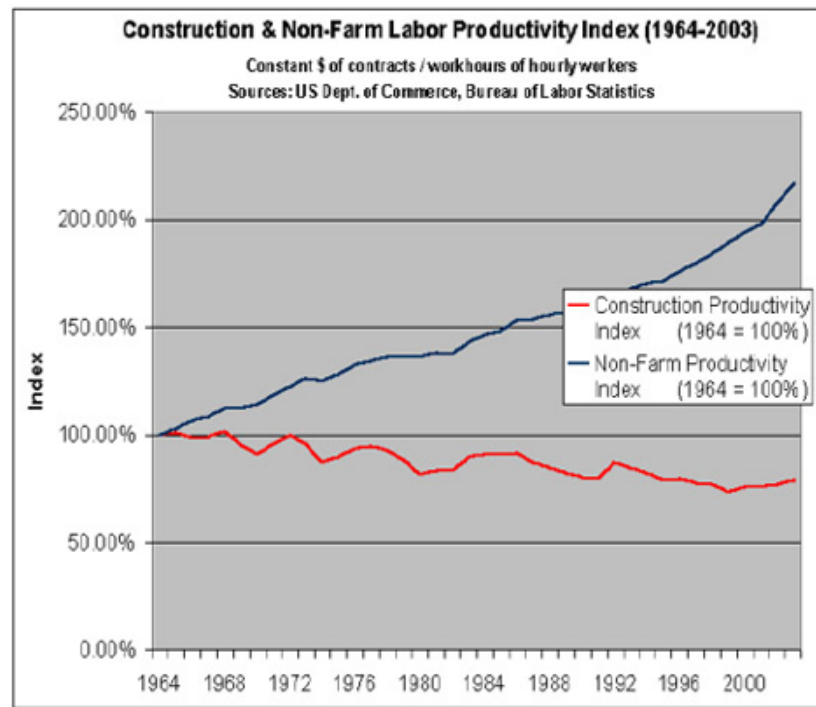
Finally, the product level BIM implementation poses challenges which are more technical and related to BIM technology development and utilisation in projects. The BIM implementation in construction industry is triggered by a complete new wave of technology and many companies consider it just a combination of some software applications. The BIM technology itself is getting mature and becoming more fit for purpose Shafiq et al., (2012) and so as its uses in the practical situations. Some researchers has stressed that although the BIM technology is generally available but it is yet a the biggest challenge towards widespread adoption of BIM (Alfred & Olatunji, 2011; Samuelson & Ab, 2010). These technology obstacles are not only software and hardware limitations but acquiring, learning and training new technology to support the BIM implementation process, such as web portals, geographic information system etc. It is well recognised fact among the construction researchers that there is yet greater need for interoperability and integration of BIM software applications and data structures for the whole life cycle of the BIM projects.

## **2.6 PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY**

Production and productivity are two different terms which are often used interchangeably in the construction industry but there is considerable difference between these terms. By definition, production is work done that contributes towards achieve a task or goal, while the productivity is an average measure of the efficiency of production that can be expressed as the ratio of inputs and outputs used in the production process (Chelson, 2010). Productivity is also called productivity rate in the construction industry (i.e. unite output per unit input). A production process can have production with low productivity which means resources (Time, material, effort etc) are being wasted in the production process and the process is not efficient. A high

productivity would mean that resources are being used efficiently to produce maximum output from the given inputs. In simple words, higher productivity means getting things done with less cost and in shortest possible time.

Productivity is a key concern in the construction industry as it is an indicator of how much time and money is going to be spent on each task, and ultimately on the project. Chelson (2010) cited from Warren (1989) that productivity in construction is completion of construction work at unit rates more economical than the other, less than those published in estimating handbooks, and better than those used in producing the estimate for a given project". The U.S. Department of Commerce defined construction productivity as "dollars of output per person hour of labour input" and there may be several types of inputs in a construction production process which need to be considered, for example land, materials, machinery, tools, and manpower (Teicholz, Goodrum, & Haas, 2001). According to the Construction Industry Institute (CII), the US construction industry nearly spent 57% of its resources, equals to \$600 billion in 2008, on non-value adding activities which do not directly contribute towards any production (Teicholz et al., 2001). CII stated that the construction industry only contributes 10% of its productivity to create value for its efforts while the manufacturing industry contributes 62% of its direct efforts to create value in the production process, as reflect in the figure 2.6.



**Figure 2.6 Productivity of the construction industry VS manufacturing industry**

*Source:* (Teicholz, Goodrum, & Haas, 2001)

The statistics of the figure 2.6 are based on the contract dollar per labour hour's inputs for both construction and manufacturing industry production operations, indicating that the productivity of the construction industry has decreased by 20% from 1964 to 2003 while for manufacturing increased by about 120% (Teicholz et al., 2001). CII report also attributed the dramatic increase in the productivity of manufacturing industry to efficient use of Information Communication Technologies (ICT), which has made the manufacturing processes more automated, reducing input efforts (waste in material and labour) and thus improving productivity (Chelson, 2010).

However, it is argued by the construction professionals and researchers that the construction industry is significantly different from the manufacturing, and automated planning and coordination of activities is not straight forward in the construction as it is in the manufacturing (Cooper et al., 2005; Lee, 2002; Moum et al., 2007). Construction

industry has some unique characteristics, for example highly fragmented stakeholders, one off projects, spatial fixity, weather condition, on site production, mobile machinery, temporary project teams, inexperienced clients and masculine-stereotype work force (Aouad et al., 2005; Cooper et al., 2005). In summary, the productivity of the construction industry has been low as compared to manufacturing industry because the construction industry has a number of constraints that inhibit the use of ICT for efficient planning and production processes.

Another key issue is that productivity in the construction industry has different meanings to different stages of a project and also varied among the project stakeholders as they may have a different perspective on productivity (i.e. design productivity, productivity for contractors, building owner's productivity). For example, productivity for a construction client is the amount of work done as per his expenditures following the given schedule, whereas a contractor may see productivity the rate at which the work is going on to maximise his profit. The following sub section will discuss some key considerations to understand the productivity in construction project stages for different stakeholders.

### **2.6.1 PRODUCTIVITY FOR OWNERS/CLIENTS**

Construction clients and project owners ultimately pay for everything in the construction process and therefore they are more concerned about productivity and efficiency as it can save them capital expenditure as well as operational costs of the project in the long run, (Park, Thomas, & Tucker, 2005). Productivity for owners is the “value” for an asset to them and to its users, measurable by the amount of output that building gives relative to the inputs required even beyond the completion of



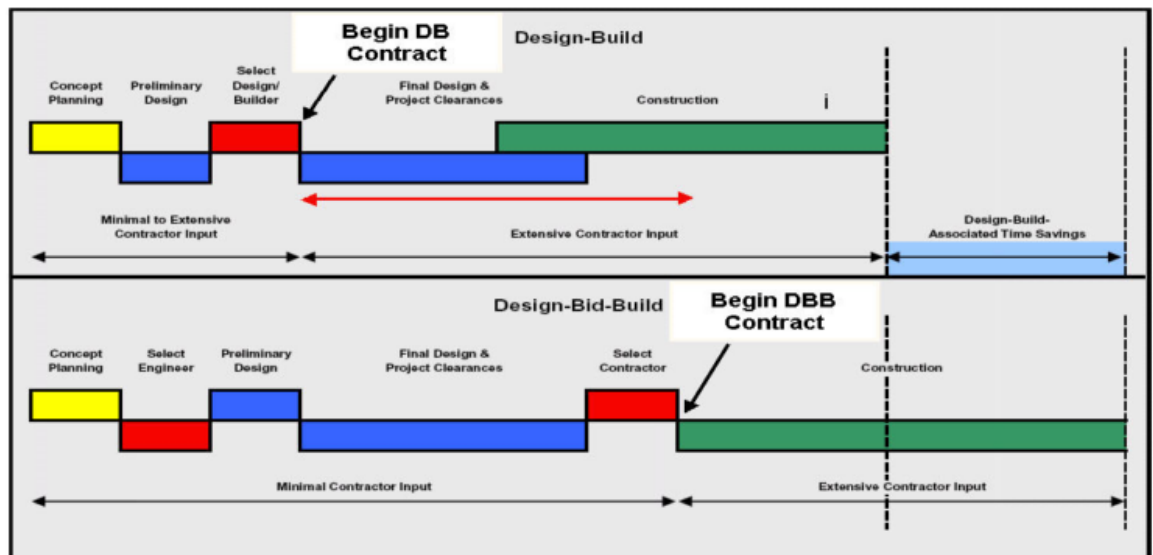
construction process, (Chelson, 2010). Therefore, the value of a built asset is not only the capital cost, but also the energy efficiency, functionality for occupants, health and safety of the users, accessibility, structural stability, aesthetics and maintenance of building components (Park et al., 2005). In addition to that, tenants and owner's satisfaction is another metric that determines productivity for clients. However, these factors are very difficult to quantify in order to determine statistical evidence of productivity for the clients and building owners. Yet these factors are important and a slight productivity improvement in some of these may potentially save quite significant cost for the clients. For example, energy efficiency has become a major issue due to increasing energy costs and pressure to reduce CO<sub>2</sub> emissions, therefore 5% improvement in energy efficiency of a build could save millions for a client in 20 years' time. Similarly, functional efficiency and adaptability of a building are critical for owners. The internal usage requirements may change with time and if the building is designed to be adaptable, it could save significant capital cost for the owners as the usage or rental will continue much further accommodating new usage requirements (Chelson, 2010). Also, efficient data create opportunities for better facility management (operations and maintenance) which is also very valuable for asset managers and building owners as it can reduce life cycle cost of the built assets.

### **2.6.2 PRODUCTIVITY FOR DESIGNERS AND ENGINEERS (DESIGN PRODUCTIVITY)**

Designers and engineers typically engage at the design process until the execution and commissioning of a project. The role of designers (architects, interior designers etc) and engineers (Structural, MEP etc) is to capture all the aspects and details of the project and communicate the design intent as precisely as possible, whereas the contractors are responsible for means and methods to execute the given design intent as per the details

and specifications. If there are conflicts and confusions among the design itself, or it contradicts with the constructability, then it will cost extra time and money and often raise conflicts among parties that end up in court procedures. Therefore, a well coordinate, clash free design is backbone of a productivity construction process.

In typical construction projects, architects are responsible for producing design and construction documents, engineers are concerned with the technical details, which are all done in discipline silos. Coordination of the design is often responsibility of lead architect which perform regular coordinate checks using layers in CAD systems to find and eliminate possible conflicts in design. However, this approach is slow, inefficient, cumbersome and unreliable because all the design information cannot be integrated using traditional CAD files in the sequential project stages (Daneshgari & Moore, 2011; Rojas & Aramvareekul, 2003). Thus, result in a large number of design conflicts which are often realised during construction leading to re-work, re-design, change orders, time delays and additional cost claims, all of which seriously reduce project productivity. This situation improves drastically if the design and construction processes overlap, which is a key feature of BIM enabled projects and integrated project delivery (IPD). Time saved in design and construction overlap is reflected in the figure 2.7.



**Figure 2.7: Productivity increase with design and construction overlap**

*Source: (Chelson, 2010)*

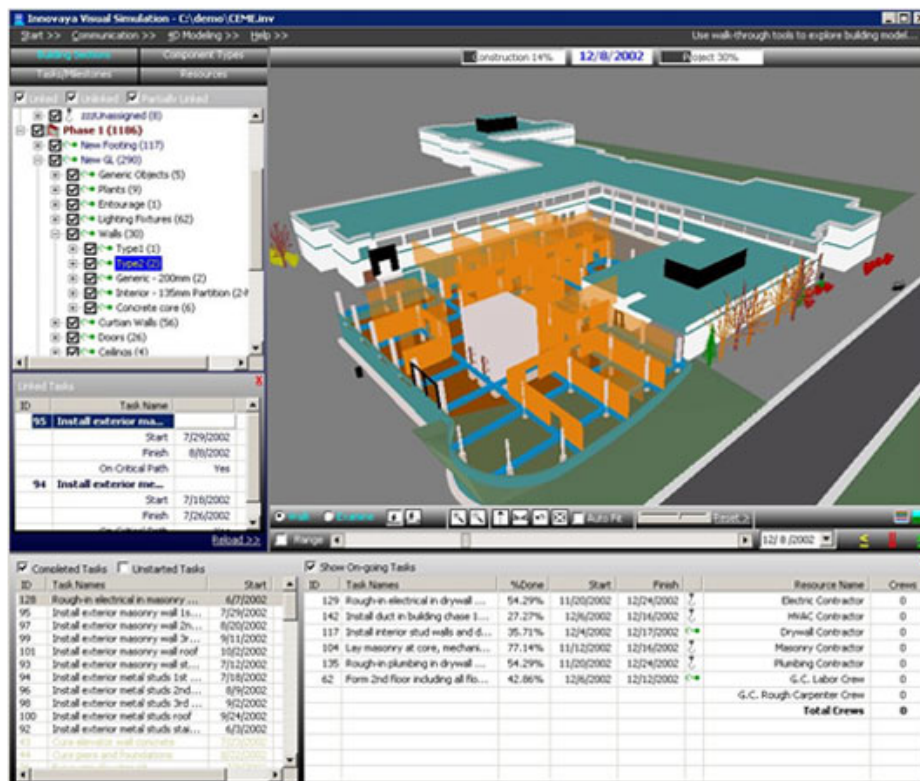
In addition, clients and owners generally do not have capabilities to read the technical details of design in 2D drawings and they only realise the actual design when it is been construction or underway physically. Designers and engineer will face an unsatisfied client if the client is not happy about the design appropriateness by that time.

### **2.6.3 PRODUCTIVITY FOR CONTRACTORS (CONSTRUCTION FIELD PRODUCTIVITY)**

Contractors are responsible for actual production, assembly and commissioning of the building elements which directly contributes to the productivity of the construction projects. A simple rule of supply and demand suggests that if more contractors are able to increase their ability to increase their productivity rate, more market competition and pressure will be developed ultimately passing the money saved to the clients (Chelson, 2010). Traditionally, designers and engineers deliver construction documents articulating “what to build” while the contractors take responsibility for “how to build” with his means and methods. The growing complexity of construction projects has

made this impractical to separate these two issues and demands better planning and collaboration among all parties to create workable and productivity solutions. Planning and scheduling are important factors that contribute towards productivity from a contractor's perspective (Daneshgari & Moore, 2011). Planning and scheduling takes time and resources upfront but it can save much more time and resources during the execution process if implemented correctly and efficiently (Park et al., 2005).

Traditionally, contractors use various project management techniques, such as WBS (Work break down structure), to schedule construction activities. WBS is a deliverable oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives, which can hamper effective project-wide coordination by dividing work into packages before relationships can be evaluated. Scheduling is typically done by scheduling programs, such as Primavera's P-3 or P6 and MS Project, are the most common software applications that uses various techniques (such as critical path method) for producing optimised schedules. The schedule accuracy important not only to determine the final project completion time but also controls the interrelation of subcontractors, suppliers, machinery and material on site. A bad schedule would cause delay, waste in material, re-work, machinery rent-time waste, labour wastage and ultimately poor project productivity (Kymmell, 2008; Moum et al., 2007; Park et al., 2005). An example of BIM enabled planning (4D modelling) is reflected in figure 2.8.



**Figure 2.8: BIM enabled planning and constructability review**

*Source: (AE, 2014)*

Constructability review is another important responsibility of a contractor, which is assessment of a design to be constructed using most efficient means and methods. It is reported by Chelson (2010) that addressing better constructability in projects tend to save 6% to 10% of the total construction cost. Latham (1994) claimed that a collaborative constructability review among designers, engineers and contractors could save up to 20% of the construction cost, which is significant productivity improvement. On the other hand, if a project undergoes a poor constructability review followed by poor scheduling, it could end up 9% performance decrease for every disrupted task. For example, a ductwork space is created and later identified that pipes do not fit in that space. This is more evident for mechanical contractors as they suffer most from low field productivity due to design conflicts and poor scheduled activities.

Another important aspect of contractor's productivity is having a good document management system to manage the drawings and documents so that correct and latest information can be issued to each stakeholder in time. Examples of such system are Meridian, Primavera, Bentley etc and project websites such as Asite and 4Projects. Delayed or wrong information can cause disasters and can significantly reduce productivity. In traditional practice, contractor's face several non-value adding activities due to traditional sequential procurement practices and adverse contractual relationships. These include waiting for approvals, submittals, request for information (RFIs), design changes and other paper management activities which are essentially non value adding and non-productive. Another productivity challenge for contractors is material procurement and management on site, which traditionally cause a lot of waste and dent productivity. It is estimated that around 10% of material brought on site is wasted in Europe (Howell & Koskela, 2000), this is ever higher in developing countries such as in KSA (Albogamy, Scott, & Dawood, 2013).

This section has reviewed productivity for different project stakeholders in construction. The next section discusses the efforts to improve the productivity of construction projects.

## **2.7 EFFORTS TO IMPROVE CONSTRUCTION PRODUCTIVITY**

The phenomenon of low productivity in the construction industry is well recognised (Egan, 1998; Latham, 1994; Oglesby, Parker, & Howell, 1989) and a number of management systems and techniques were developed to improve the overall productivity of the construction industry. Some of these efforts are briefly introduced in the following sub sections.

### **2.7.1 LEAN CONSTRUCTION**

Lean construction emerged as a management technique focusing on value adding activities and reducing or eliminating unproductivity work or activities (Howell, 1999). The principles of lean construction were borrowed from automobile industry (e.g. Toyota production system) that advocates concurrent and continuous improvement of the construction processes with minimum cost and maximum value, (Hardin, 2009). The basic idea of lean construction is to reduce the number non value adding activities, such as waiting time in approvals, waiting time in material arrival etc which do not add directly to the productivity of the construction process. A number of authors has shown that lean construction can bring significant productivity improvements by saving labour hours and cutting time wastage (Howell, 1999; Howell & Koskela, 2000; Seed, 2010). However, this is a management technique that requires partnering and strategic collaborations among construction stakeholders, which is difficult to achieve in traditional project setting.

### **2.7.2 PULL FLOW OR PULL CONSTRUCTION**

Pull construction is another application of lean construction philosophy which advocates allowing shortest possible time for detailing and fabrication of building components where possible to avoid re-work and last minute changes, (Eastman et al., 2008). This is effective because the exact requirements and specification for equipment and installations are seldom known until very late in the project. Pull construction technique suggest to delay the shop drawings and fabrication until last possible time, so that any change in design may not cause a delay or re-work. Hence, shop drawings and

detailing is only done once, decreasing non value adding activities and reduce wastage time that may be spent in rework, (Chelson, 2010).

### **2.7.3 LAST PLANNER SYSTEM**

A person or group that determines the specific details of any work in least possible time is called Last Planner, who has most control over the productivity at any unit level and this is considered pivotal in proper planning for effective and efficient operations, (Seed, 2010). Last planner system suggest giving the scheduling authority to the last person in the chain as drive direct work rather than just planning of plans, (Ballard, 2000). Traditional construction schedules are prepared for three to five weeks look-ahead activities, but the actually focus is generally on “what should be done” rather following the schedule. Last planner system allow the on-site planner to refine the process by evaluating task and their assembly according to the baseline project plan, so that the task and assignments can be achieved in most productivity way. Last planner system has been implemented on a number of case studies all around the world, including KSA, and has reported several productivity improvements (AlSehaimi, Fazenda, & Koskela, 2013; Bhatla & Leite, 2012; Seppänen, Ballard, & Pesonen, 2010).

### **2.7.4 JUST-IN-TIME (JIT)**

JIT is another practice emerged from Toyota Production system philosophy that is often used in combination with lean construction techniques to reduce waste and time to gain productivity improvements (Pheng & Chuan, 2001; Tommelein & Li, 1999). JIT approach is particularly useful in project which has tight spaces or ridged schedule



constraints, such as projects in city centres or skyscrapers where material cannot be stored on site before it is actually needed for production. JIT principles have been widely adopted and successfully implemented in manufacturing industry and is also being experimented in the construction industry to reduce processing and storing of equipment and forces planning of labour and material coordination (Kee-hung & Cheng, 2012). JIT enables “mass customisation” by directing work towards most cost effective method to produce the end product rather than producing each component that simply means only taking delivery from supplier when it is actually needed on site rather having material or equipment already dumped on site (Chelson, 2010). Although the JIT philosophy has been strongly advocated to benefit construction industry but its implementation has not been much successful due to required logistic planning with computerised control systems which are difficult to achieve in the construction site environment, (Pheng & Shang, 2011).

#### **2.7.5 TOTAL QUALITY MANAGEMENT (TQM)**

TQM is another well-known production control and management system which suggests developing standard operating procedures and compliance with predefined specifications to optimise project procedures for better and more productive outcomes. TQM systems have been useful to bring productivity improvements in manufacturing industry but their application in construction is still limited due to dynamic site conditions and temporary project setting. The ISO (International Organization for Standardization) 9000 family is a quality assurance system that puts quality-management process into effect before work begins and detects and corrects problems before they reach disastrous proportions. Large construction companies are, generally, ISO 9000 certified and have developed standardised operating procedures, manuals and

work processes and instructions. By doing so, rework is reduced by clarifying specifications and defining the method to achieve the results desired and thus improves productivity. Six sigma is another application of TQM which can reduce waste by adapting to standard procedures and management practice. Construction and design firms tend to have difficulties implementing this system fully because of extensive paperwork involved and pervasive nature of construction work.

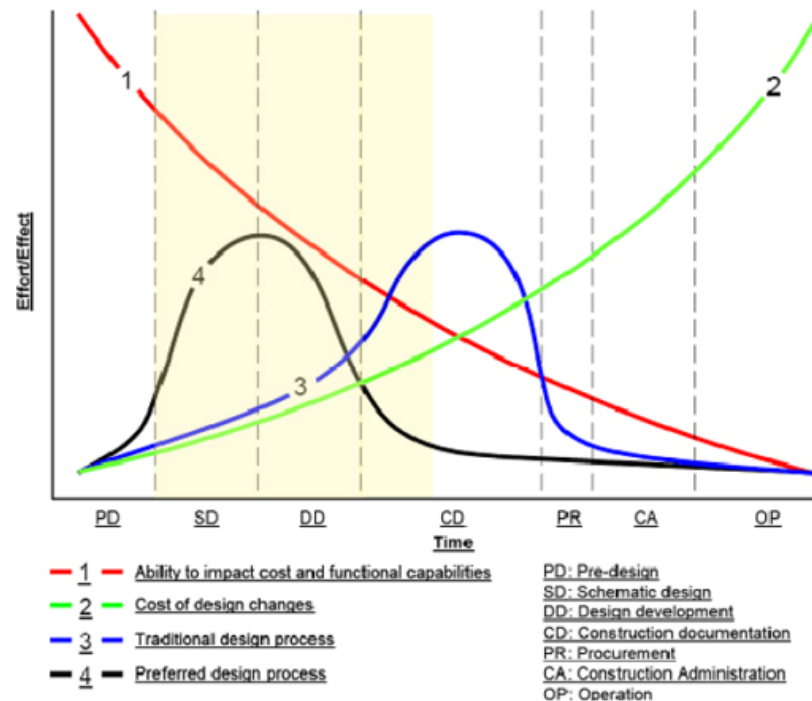
#### **2.7.6 PREFABRICATION**

It is evident from the above discussed productivity management techniques that the key hurdle in productivity improvement in construction is uncontrolled dynamic site condition and job environment which is not favourable to directly apply productivity improvement techniques which are generally developed for fixed working conditions as in manufacturing industry. Therefore, construction researchers have consistently supported the idea for prefabrication by transferring construction work load to factories as much as possible where controlled condition can be applied for better productivity, (Howell & Koskela, 2000; McGraw-Hill, 2012; Tavares & Grilo, 2000). Prefabrication of construction competent can apply several productivity improvement techniques in order to achieve required cost and quality in controlled environments. Standard size materials increase productivity rates because they provide consistency for the workers and allow planning of materials to be accomplished more quickly and with less waste (Björnfot & Sardén, 2006). Prefabricated components are assembled on site with less effort and save huge effort that is required otherwise for shop drawings, submittals, design changes and approvals. However, prefabrication still requires precise and accurate information to start manufacturing process, which is still difficult using traditional 2D CAD as exact dimensions are unknown until very late in a project

(Jaillon, Poon, & Chiang, 2009). For example MEP (mechanical, electrical & plumbing) systems details are not produced until measurements of existing conditions are taken on the job site, which is then checked and verified with shop drawings and filed dimensions. Prefabrication can greatly improve construction productivity (McGraw-Hill, 2012) but it requires precise information upfront in design stage which is difficult with traditional CAD systems and required more accurate and integrated information which is possible with Building Information Models.

## **2.8 BIM AND PRODUCTIVITY**

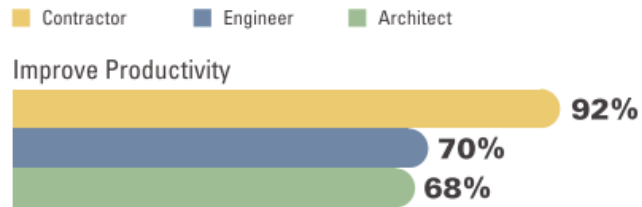
The introduction of BIM has shown strong potential to deliver significant productivity improvements throughout the life cycle of construction projects, (Bryde, Broquetas, & Volm, 2013; Eastman et al., 2008; Kymmell, 2008; NBS, 2013). In particular, BIM can re-engineer the construction planning and production process with the use of virtual modelling and simulation (4D modelling) that can increase construction productivity by reducing the wasteful activities and knowing the unknowns in advance, (Mahalingam et al., 2010; Turkan et al., 2012). The data rich 3D BIM model and 4D simulations enable BIM to efficient the design and construction processes by using a variety of productivity improvement methods, as outlined in the above section. For example, BIM is a collaborative process that applies lean construction principles to reduce wasteful activities in design and construction. BIM enables prefabrication by providing accurate information, reduce process and material wastes. A key aspect of BIM is its ability to shift design decision making earlier in the project process, where changes and errors have far less impact on the project productivity parameters (i.e. cost, quality, time), this is reflected in the Figure 2.9.



**Figure 2.9: Productivity improvement with BIM**

*Source: (Chelson, 2010)*

Productivity improvements with BIM becomes evident even on early design stages, as building components are designed in 3D which removes design conflicts and provide greater understanding of space utilization and construction before the action work starts. Clash detection and design coordination reduces the number of errors and can potentially save a significant percentage of total project cost by reducing rework and delays that result in cost overruns. 4D BIM has revolutionised the planning and scheduling practices for the construction stage. A number of researchers have reported that resources spent on modelling design information in BIM saves much more effort during construction due to less changes, less RFIs, fewer rework and delays. These claims are supported by a number of surveys, for example McGraw-Hill survey reported that over 90% contractors are using BIM for increased productivity, along with 70% engineers and 68% architects for the same reason.



**Figure 2.10: Increasing use of BIM for productivity improvements**

*Source: (McGraw-Hill, 2012)*



**Figure 2.11: Impact of BIM on productivity**

*Source: (McGraw-Hill, 2009)*

Figure 2.11 reflects more detailed statistics on how BIM has impacted the construction production and delivery. It is evident from figure 2.10 that use of BIM has improved productivity in terms of time saving by error reduction, avoiding rework and collaborative working, which eventually result in cost savings and better quality projects.

The previous sections have discussed construction productivity from various stakeholder perspectives (i.e. Owners, designers, engineers and contractors) and how BIM offer productivity improvements for all project stages and thus benefits all the project stakeholders. However, measuring the productivity improvements and quantifying the potential savings for all the stakeholders are not straight forward tasks. Some productivity improvements are more measureable than others. For example, number of clashes resolved using BIM can determine the time and effort saved, which can be quantified to provide an evidence of tangible productivity improvement. However, meaning client satisfaction, improved design quality etc. are difficult to quantify and hence generally referred as intangible productivity improvements. This study will only focus on measureable and tangible productivity improvements which BIM can bring in design and construction stage.

An important issue to understanding is the “net BIM effect” on productivity increase, as BIM effectiveness is usually in terms of cost avoidance as it reduces waste, change orders, re-work which potential save money, (Chelson, 2010). However, this is only a part of productivity improvement which BIM can bring. Another side is the increase of productivity rates using 4D model enabled planning and scheduling practices, which can greatly benefits contractors and owners. The business case for using BIM for owners and property developers is generally built around BIM capability to enhance

facility management opportunities but it can also benefit them by providing faster schedules, earlier commitment of costs and the reduction of unanticipated costs or changes. If a BIM model is well coordinated and clash free, it can reduce the RFIs by a factor of 9 and reduce the change orders during construction up to zero, (Kymmell, 2008). Together, it saves time and effort leading to cost avoidance and also increases productivity rate by reducing the time spent on non-productivity activities that do not directly contribute to the final product. This is the “net BIM effort” on productivity, which is anticipated to bring significant improvements in the overall productivity of the construction project and ultimately to the construction industry. However, in order to calculate the BIM net effect on productivity, there is also need to consider the additional cost of implementing BIM (software, hardware, training etc.) and the compare the productivity of BIM projects verses non BIM or traditional projects.

### **2.8.1 RETURN OF INVESTMENT (ROI) WITH BIM**

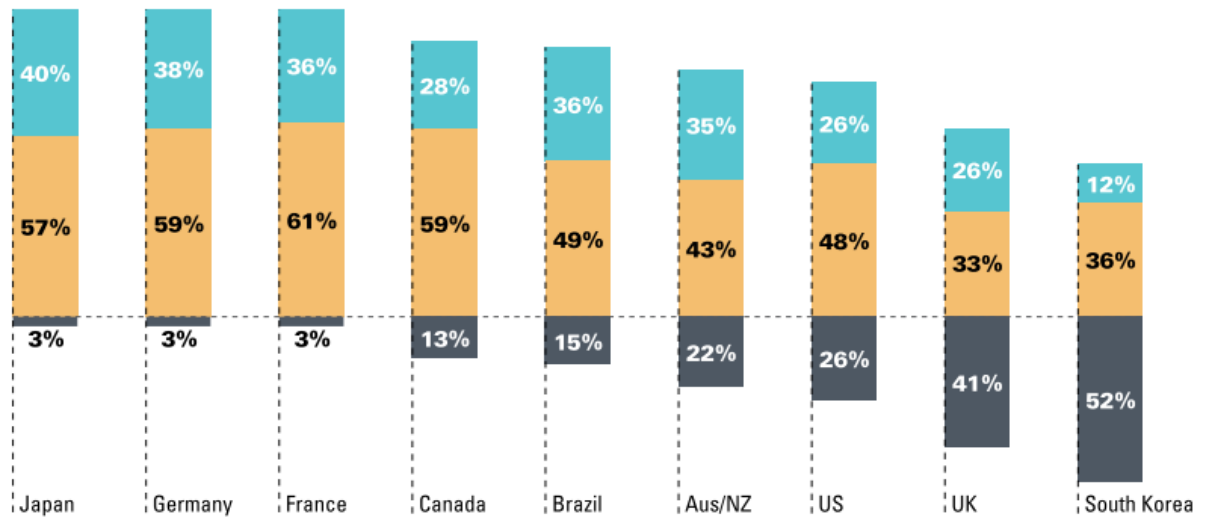
The return of investment (ROI) and productivity increase will only truly be known when net BIM effect (cost avoidance + cost saving) is compared to determine the cost savings associated with employing specific BIM practices. The cost avoidance is measured using how many clashes or changes were eliminated which could have saved extra costs in terms of man hours and resource utilization. But the general figure of potential savings and ROI varies among the claims of software vendors, academic BIM advocates and industry experts. Although there is no general consensus on how much productivity increase is possible with BIM, the average predictions and claims are in the range of 10% to 30% of the total project cost. Consulting engineers and designers generally report these figures higher as 50% due to BIM software benefits to them, such

as production of automated drawings, and documents from BIM models. Some examples from literature are:

- BIM implementation is estimated to bring latest 2 to 1 on ROI and 10% increase in labour productivity (Carbasho, 2008),
- Designers, especially architects, can gain up to 50% increase in their productivity as more than half of the users have reported average 50% productivity increase,
- Engineers (structural, MEP) can decrease 47% in their labour hours on design and manage projects,
- Construction site productivity can be improved by 15% to 30% with effect BIM uses as compared to non BIM projects, according to the existing industry standards of productivity (Khanzode, 2007),
- ROI on BIM is between 1 to 30% according to AGC BIM forum members, (Young, 2008).

Contractors have generally reported positive return of investment on BIM, as reflected in figure 2.12.





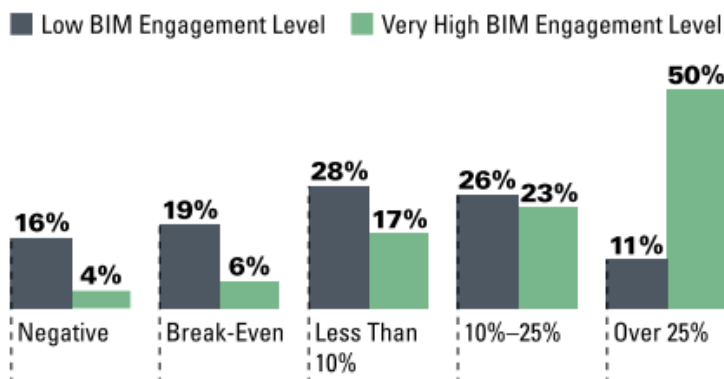
**Figure 2.12: ROI on BIM projects**

*Source: (McGraw-Hill Construction, 2014)*

The blue colour in figure 2.12 represents very positive ROI (over 25%), orange colour reflects moderate ROI (up to 25%) and black colour shows where people have reported negative ROI on BIM projects. It is worth mentioning that the level of engagement in BIM projects plays a vital role in perceiving ROI, as more engaged and experienced contractors have reported positively and vice versa, as reflected in figure 2.12.

### **Contractors' Perceived ROI on BIM (According to BIM Engagement Level)**

Source: McGraw Hill Construction, 2013



**Figure 2.13: BIM engagement and ROI**

*Source: (McGraw-Hill Construction, 2014)*

As aforementioned, construction sector is a key contributor of economy of any country and a tiny improvement in productivity of this sector would result in huge savings, and a 20% increase would have revolutionised impact. Moreover, the cost savings with BIM is not re-distribution of wealth (i.e. from labour to owners) but rather an elimination of waste activities and costs which will benefits all stakeholders in the supply chain, especially the contractors, and ultimately to the project owners. A theoretical example of calculating ROI and predicting productivity increase with BIM implementation is presented by Autodesk (2012), which is based on the longitudinal experience of the Autodesk's consultation over the years. The approach is based on the following key points:

- Initial cost assumption: BIM implementation cost an average 0.5% of the total program budgeted (mainly for hardware upgrade, software licencing, training and education). This is an initial cost investment which is generally accepted by the industry for large projects or programs intended to implement BIM.
- Cost overruns saved with BIM: BIM can reduce cost overrun in project delivery by 15% (a modest estimate considering the industry average claims from 10-40 % savings). This is usually saved due to reduction in RFI, reduced change orders; time saved in drawings & documents production and reduced lead time in production.
- Cost savings after project close: This is estimated to be at least 5% of program budgeted, which is generally the time saved in production of as built documents and accurate assembly of installed products and building systems due to information accuracy by virtue of BIM.

- Cost saving by scope clarity: Savings due to better visibility of the contractors' cost breakdown is factored into both the bidding and negotiation phases, as well as controlling the as-built. An average saving of about 5.5% of the total program budget based on industry experience in major capital projects where BIM is implemented.

So, in theory, the resulting savings with BIM implementation can lead to 20 times the original return of investment over three years period, according to the above calculations, Autodesk (2012). However, these calculations are conservative as it represents a technology BIM adoption perspective from a software vendor as they may have their own business agendas. This merely reflects a limited example of ROI calculation as focusing in a particular view and there are many more aspects to be considered, both in terms of initial cost and also in calculating potential savings with BIM. Also, these calculations assume that the efficiency increase and reduction in cost overrun would only be achieved gradually and progressively over the course of three years. A more immediate increase in efficiency would improve the ROI calculation significantly. A more detailed ROI analysis would also take quantitative project execution processes into consideration (staff/roles, tools, manual or automatic tasks, artefacts/data objects/inputs & outputs, resources/costs/time) (Autodesk, 2012).

### **2.8.2 KEY PERFORMANCE INDICATORS (KPI) FOR PRODUCTIVITY INCREASE AND ROI**

It is evident from the above sections that BIM has been perceived as a vehicle to improve productivity but measurement of productivity increase and associated return of investment on BIM vary greatly among different authors. This is linked with the multifaceted understanding and a wide range of BIM uses (as explained in chapter 2) in

construction projects, as well as among various industry stakeholders. An important observation from the literature is that the adoption of new technologies is always accelerated by (1) Government push or legal requirements (2) Client's contractual obligations and (3) proven economic benefits. BIM adoption has already been backed by different governments and large clients all around the world but the economic benefits of BIM are yet unclear and requires more research. As mentioned earlier that BIM adoption has numerous challenges for maximum benefits related to technology, process and people to bring a complete change in the way construction industry operates. However, if economic benefits of BIM become clearer, so unavoidable that all the challenges in technology upgrade, training, expenses of implementation will become overwhelmingly justified.

Therefore, benchmarking the productivity improvement with BIM is a key research area that need to justify and validate the business case for BIM determining productivity improvement and also the return of investment. The cost of BIM implementation depends on a number of factors, which is discussed in literature, these are:

- Type/family of software being used.
- Required level of detail (LOD) by the client on various construction stages, which determines the BIM maturity level.
- Personal experience and expertise of construction team with BIM processes and technology.
- Knowledge and BIM maturity level of the client.
- Complexity and uniqueness of the project.
- The start of collaborative process in BIM projects (e.g. early involvement of contractor etc).
- Type of project procurement and contractual setting (e.g. Project delivery environment).

Management of all these factors is critical in order to determine productivity improvements and how much money BIM can save against the investment of time and resourced applied. The knowledge of expected cost saving would enable the clients and project teams for proactive decision making.

Construction executives and project leaders need to have proper knowledge of adopting BIM to gain perceived or possible advantages need to know the cost of implementation and the amount of expected savings through implementing BIM. The value of BIM is the amount of money that can be saved by increasing productivity less the amount of the cost of performing the process. This value needs to be determined through a number of factors, which are called key performance indicators (KPIs), the knowledge of which will enable intelligent and upfront decision making regarding BIM adoption. So far, construction industry is replaying in case studies and project testimonials that claim various numbers about what BIM ha potentially saved for them. These numbers varies because the underneath KPIs to calculate the productivity improvement and ROI are different and thus lead to different results.

The underlying assumption of this study is that BIM increases productivity, especially with 4D modelling that improves planning inefficiencies resulting in construction field productivity improvement. This assumption is generally accepted by academic and industry, but how much BIM can save is yet debatable and worth investigating. The question is “how productivity increase can be measured? Or “what KPIs can determine if there is any increase in productivity or vice versa”? In generally, a number of KPIs are discussed in literature that can measure productivity improvements, such as cost reduction, waste reduction, energy efficiency, sustainable design and production, carbon

footprint reduction, lesser RFIs, fewer unplanned changes, higher customer satisfaction and less disruption in project process, (Chelson, 2010; McGraw-Hill Construction, 2014). It is noted from the literature that the metrics to measure productivity and return of investment are region specific and it can differ greatly depending upon the circumstances of a market. For example, energy consumption and carbon footprint reduction are on top of agenda in the UK due to legislations and high energy costs, where these metrics are not important in the KSA construction market because of oil driven economy and cheaper energy costs. The research should provide data needed to make accurate claims about productivity improvement with BIM in line with the ROI. This research has determined following KPIs from literature, which can help to determine construction productivity and ROI on BIM projects.

- **RFI (REQUEST FOR INFORMATION)**

The number of request for information (RFI) on a project reflects design clarity and level of collaboration among the project participants. In general, total number of RFIs determine efficiency of the overall project process. A high number of RFIs reflect a poor design or incapable project teams that is more likely to end up cost and time over run in the project. A low number of RFIs represents a well-coordinated design and delivery process where minimum time is wasted to clarify the project scope and specifications. The formal process of generating and managing an RFI is quite time consuming and often involves wait time in traditional project practices that result in potential recourse and time wastage. BIM project has generally reported low RFIs because all the design information is synchronized and coordinated in a single model, which reduces the chances to generate an RFI during construction stage.

Potentially, every clash detected in design stage using a BIM model saves an RFI at construction stage and thus save the man effort, paperwork and time to resolve that clash at construction stage, which can be converted into cost savings. The cost savings due to fewer RFIs in terms of administration and lower field productivity, and the number of RFIs avoided on a project with BIM adoption would indicate the cost and time impact of BIM on a project towards increasing construction field productivity.

- **DESIGN AND PRODUCTION CLASHES**

Clash detection with BIM model is a very powerful tool at design stage as it can resolve hundreds of design conflicts before they actually cause a real problem during the construction stage. Similarly, 4D modelling can be used to rectify production stages clashes (e.g. machinery movement clashes, temporary structures, material handling, workable spacing etc). The number of design and production clashes resolved with BIM model can also be converted into possible cost and time savings achieved with the use of BIM model, which would a good measure of BIM enabled productivity increase.

- **CHANGE ORDERS**

Change orders typically reflects rectifications in original design, either due to a design fault, constructability issue or if the client changes his mind to impose a later stage change. The change orders are extra costs which would be paid to contractors by clients when the site conditions differ from the original contractual documents. Change orders are typically associated with RFIs, as an RFI can result in a change order. More number of RFIs will leave more chances for change orders, which generally add significant

added cost in the overall project budget. It is not uncommon for clients to consider at least 5% to 10% contingencies in construction budget as a result of change orders.

On a project, the number of change order reflects the amount of confusion and costs associated with delays due to poor information, change of work, or re-work after a problem is discovered and resolved. The cost of a change order greatly varies, depending upon the nature and condition of a change order. BIM can greatly reduce the number of change orders as it offers strong visualization of project design at earlier stages and provide collaboration opportunities to clarify the scope and specifications during the design stage. So, if a project score lower change orders with using BIM as compared to a similar traditional project, it would reflect productivity improvement. It is worth noting that some change orders are unavoidable due to unforeseen condition during the project execution phase, which is not being questioned here.

#### ▪ **SCHEDULE COMPLIANCE**

The compliance of planning schedule is another indicator of construction productivity. Project planners and construction schedulers should be able to efficiently plan the project activities, set the project milestones and anticipate how well the crews are able to meet the productivity challenges against the given plan and schedule. If there are less delays due to a good project plan which has put the activities in correct order of execution, the schedule will be faster and the project anticipated completion date is more likely to be achieved more often. A correct schedule is also important along with building faster in order to coordinate different tasks and avoiding any bottlenecks or lead time which may be wasted due to a poorly scheduled construction plan. The project managers and contractors perceive satisfactory project progress from an on track schedule and it is often the most important indicator of project productivity. Schedule



compliance is represented by how close the task is to its projected duration and is given as a percentage of time variance. Here, a positive or negative variance is not desirable because the issue is accuracy more than speed. Scheduling with BIM models, using powerful simulations with 4D modelling, can provide a more realistic and achievable construction schedule, which will be a strong KPI of productivity improvement on BIM projects.

- **DELAY TIME**

Project delays are a major cause of poor productivity of the construction industry. Delay is measured from the point when a project activity/task is halted or slowed until progress is resumed as per plan and schedule. There may be many reasons of delays, such as related to RFIs, design conflicts and clashes, missing information or plan conflicts, poor allocation of work tasks to workforce that that may or may not be directly contributory to completing the finished product. However, in all cases, time is required to fix the problem, re-schedule or change the tasks that ultimately consume more time, resources and efforts causing delay in the project timeline. Therefore, delay time can be a KPI to determine if BIM can actually improve the construction productivity. If a BIM enabled project causes less delay time as compared to a traditional project in similar capacity then it is an increase in productivity and vice versa.

## ▪ **PRODUCTIVITY RATE**

Productivity rate has been discussed in this chapter, which is a KPI that shows how effective field personnel are contributing his efforts towards the finished product. The measurement of productivity rate may have different units, such as units/hour, unit/dollar or total hours/dollar expended etc. The productivity rates can be compared for non BIM and traditional project to see if BIM processes has actually improve the productivity rate.

## ▪ **PROJECT VARIABLES**

Project variables are size, cost, type, delivery method, complexity, uniqueness, site environment etc, which can have a greater effect on KPIs that determine productivity improvement. For example, an easily accessible construction site cannot be compared with same KPIs to a site in a busy city center area. The reported productivity improvement on BIM project is for mixed projects, irrespective of considering the impact of project variables. A large size project may gain more productivity improvement with BIM utilization resulting in significant cost savings as compared to a small size, low budgeted project. Similarly, BIM can be more effective to improve productivity in a design-build or integrated project delivery environment as compared to traditional design-bid-build projects. There are no studies which has measured productivity improvements with relevant project variables against the KPIs of productivity measurement.

It is suggested that the most effective way to evaluate the changes in the key performance indicators (KPI) is against a matrix of these classifications, with

complexity and size being the most significant. The result of the study is anticipated to show how different variables affect the overall productivity rates of construction projects, (Chelson, 2010).

In summary, BIM is a vehicle for productivity improvement and business transformation; it requires significant investment and poses distant challenges at every level of organisation and project level BIM implementations. Successfully implementing a BIM process requires vision, leadership, and carefully managed organizational change. As such, return on investment (ROI) is a primary consideration for business and government leaders considering the move to BIM. The ROI of BIM implementation generally measures key performance indicators (KPI) as discussed above. Other KPIs may include turnaround times (time effectiveness), revenue per head, reduced costs of traditional approach (printing, travelling), business won (bids won percentage), or overall client satisfaction, (Autodesk, 2012). The most quantifiable KPIs and ROI result from better coordination, clash detection, and fewer RFIs and change orders, schedule compliance, delay times and other project variables.

## **2.9 SUMMARY**

This chapter has provided deeper understanding of BIM related concepts and terminologies and the impacts of BIM on construction productivity. Firstly, this chapter has presented BIM definitions as a (1) technology; (2) process and; a methodology from a number of literature sources including software vendors, the industry and professional institutes and academics. The chapter has discussed the nature of BIM as technology and collaborative processes which gives BIM advantage over traditional CAD practices. Secondly, the chapter presents understanding of BIM dimensions and various uses of

BIM, focusing on BIM uses in design, construction and facility management. BIM tools and software applications are presented for an overview of the available BIM technologies. The barriers to the adoption of BIM at an organisational, process and product (technology) level are explored. Following that, productivity in the construction industry is explored with detail. This chapter has reviewed the literature exploring the efforts to increase the productivity of construction industry.

## **CHAPTER 3 : BIM ADOPTION - GLOBAL AND KSA PERSPECTIVE**

### **3.1 INTRODUCTION**

This chapter presents presents a global view of leading exemplars of BIM adoption, including GCC countries. Firstly, this chapter discuss BIM adoption in the USA, Scandinavia, UK, Hong Kong, Australia and New Zealand, which shows that BIM adoption in these countries is driven by government policies and mandatory requirements enforced by large clients (both within public and private sectors) . Also, these countries are using BIM from a number of years, completing many successful projects, setting standards and examples for the other countries to follow. The second half of this chapter discusses BIM adoption in the GCC countries, especially as in the UAE, Qatar and KSA. However, the construction industry of KSA is focused more due the research context. The review of BIM adoption in the GCC countries suggest that BIM in this region is mainly driven by individual company or departmental initiatives, mainly influenced by growing global success of BIM in developed countries. A detailed overview of the KSA construction industry discussing its huge scale and associated problems is presented. Then the applications of BIM are revisited in the context of the KSA construction industry, highlighting their potential to improve productivity in various aspects of the KSA construction industry. Finally, this chapter discusses the BIM implementation potential in present context and highlight the need for this research. Many BIM enabled projects already exists in these countries and even more being planned, yet these countries do not have any government backed policies or mandate to speed up the BIM adoption process.

### **3.2 BIM ADOPTION AROUND THE GLOBE**

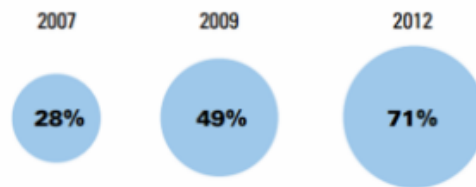
The potential of BIM has been well recognized all around the world for bringing radical improvements in the construction industry. Initially, recognized as a new wave of technology to visualize and coordinate project information, BIM is now believed as paradigm shift, a process driven methodology to enable collaborative working in the construction projects that has numerous benefits from inception stage to facility management and beyond. A number of research projects, industry reports and surveys have shown successful BIM adoption in most of the developed countries, (CabinetOffice, 2011; McGraw-Hill Construction, 2014; McGraw-Hill, 2009, 2010). Good examples are Scandinavian countries, USA, UK, Singapore, Australia, Germany etc. A very recent survey from McGraw Hill has showed that Japan, South Korea and New Zealand are going to represent the next tier of maturity in BIM adoption, (McGraw-Hill Construction, 2014). Following sections discuss BIM adoption in countries which are pioneer in BIM adoption.

- **BIM IN USA**

The USA is among the top tier of BIM adopters since the last decade and in many ways an inspiration for other countries to follow in BIM adoption and practices. In 2006, GSA (General Services Administration) mandated that new buildings designed through its Public Buildings Service use building information modelling in the design stage.

### Levels of BIM Adoption in North America

Source: McGraw-Hill Construction, 2012



**Figure 3.1: BIM in the USA**

*Source: (McGraw-Hill, 2012)*

In the USA, the GSA is the main public client implementing BIM in the public sector, which launched their BIM programs, 3D-4D, in 2003. NIST (National Institute for Standards and Technology), has conducted a number of research projects on various aspects of BIM and has published reports, guidelines and supporting document for BIM adoption which are internationally being used. CAD/BIM Technology Centre is a research centre for the US Army Corps of Engineers, providing technical and professional services for BIM deployment across the professional services in a consistent manner that ensures acceptable return on investments and promotes interoperability between BIM and other geospatial technologies. Construction Engineering Research Laboratory of the Corps of Engineers with the support of its other laboratories is transforming the use of BIM and is a primary player in the industry transformation with products such as COBIE (Construction Operations Building Information Exchange) (Wong, Wong, & Nadeem, 2010). USA academic institutes have actively participated in developing BIM standards and guidelines (e.g. BIM execution planning guide), along with professional bodies (e.g. AIA, AGC), which have helped not only the USA construction industry but around the globe for BIM adoption and implementation. As a result, a number of successful BIM projects emerged quite early in the USA, showing positive return on investment (figure 3.2 reflects an example

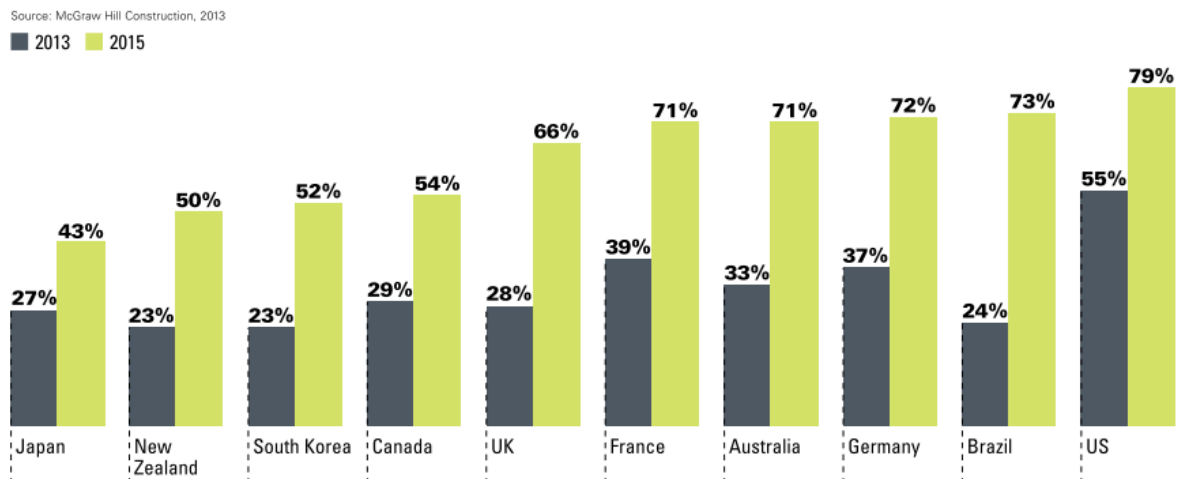
project). It is a 320 Million USD Sutter Heath Eden Medical Centre in Castro Valley, California.



**Figure 3.2: An exemplary BIM enabled integrated project**

*Source: (Jones, 2012)*

The figure 3.3 shows that USA is on top for BIM adoption and its adoption in USA is still growing faster than any other country.



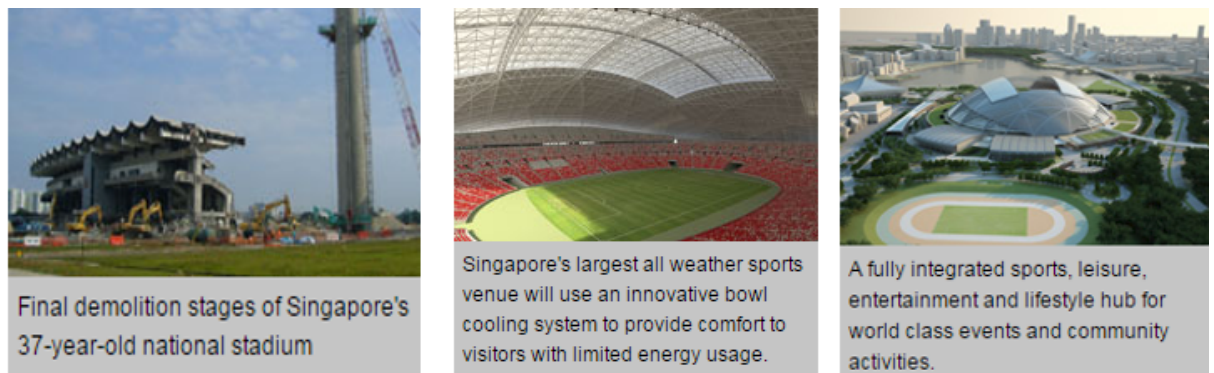
**Figure 3.3: BIM adoption comparison of different countries**

*Source: (McGraw-Hill Construction, 2014)*



- **BIM IN SINGAPORE**

Singapore is at forefront of adopting digital technologies, even before the word BIM became popular after 2003. In 2010, Building and Construction Authority (BCA) implemented the BIM Roadmap with the aim that 80% of the construction industry will use BIM by 2015. In Singapore, Construction and Real Estate Network (CORENET) is the main organization involved in the development and implementation of BIM for government projects. It is a major information technology initiative that was launched in 1995 by Singapore's Ministry of National Development. In the private sector, consulting engineers such as Arup and WSP have embarked on the implementation of BIM in their projects. Some example BIM projects in Singapore are reflected in figure 3.4.



**Figure 3.4: BIM project examples in Singapore**

- **BIM IN SCANDINAVIA**

The Scandinavian countries (Denmark, Finland, and Norway) are very advance in the use of BIM and have mandated the use of BIM on key public-sector projects. In Denmark, the Danish state clients such as the Palaces & Properties Agency, the Danish

University Property Agency and the Defence Construction Service require BIM to be used for their projects, (Wong, Wong, & Nadeem, 2011). There are at least three public owners who have initiated work on BIM in Denmark, which are; The Palaces and Properties Agency, The Danish University and Property Agency and Defence Construction Service. A number of other Government and private sector clients in Denmark have recognised the BIM potential and mandated its use, such as Gentofte Municipality, KLP Ejendomme, Bips etc, (Wong et al., 2010). Statsbygg is the state client promoting the use of BIM in Norway. Norwegian Homebuilders Association encourages the industry to adopt BIM and IFC. In the private sector, Selvaag-Bluethink is developing IFC-based BIM. SINTEF is the leading organization conducting research in BIM. Some example BIM projects in Norway are presented in Figure 3.5.



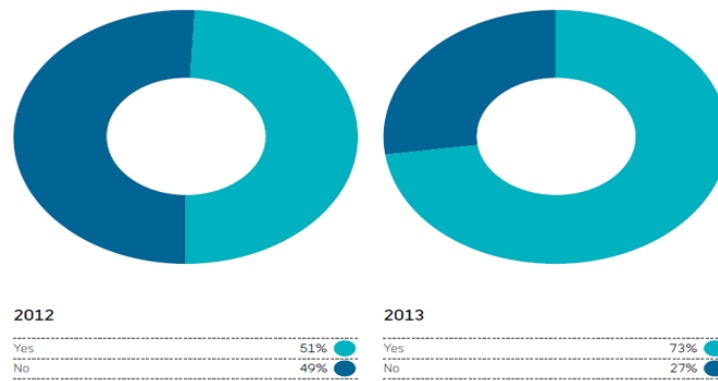
**Figure 3.5: Example BIM projects in Norway**

Similarly, Finland has mandated the use of BIM as the state property services agency, Senate Properties, requires the use of BIM for its projects since 2007. Tekla has promoted BIM in Finland and the Association of Finnish Contractors has also promoted BIM, in association with state client senate properties. Helsinki University of Technology and Tampere University of Technology are the educational institutions performing R&D in BIM. VTT is the major research organization in Finland for BIM and other research in the construction and built environment, (Wong et al., 2010).

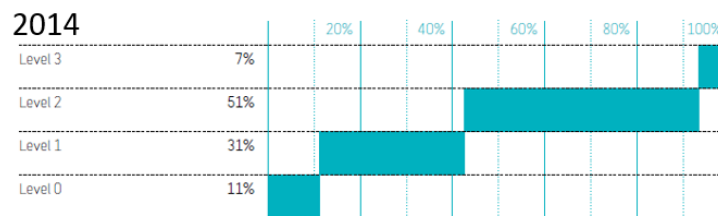
- **BIM IN THE UK**

The use of BIM in the UK has been accelerated after the announcement of UK Government construction strategy in 2012 that mandated the requirements of at least level 2 BIM by 2016 on all significant public sector projects, (CabinetOffice, 2011). A survey by NBS (National Building Specifications) in 2012 showed that the percentage of the industry actually using BIM has grown to 39%, up from 13% in 2010. The number of non BIM users, who were unaware of BIM were reduced from 43% to just 6% in the same period. The next year survey (2013) even showed a better industry take on BIM adoption, increasing the BIM users up to 73% and industry in the UK looking to reach level 2 target by 2016, (Reflected in figure 3.6)

The Government has described there being different levels of BIM.  
Are you aware of these different levels?



What level would you say is the highest level your organisation has reached on a project?



**Figure 3.6: BIM awareness and adoption in the UK**

*Source: NBS, 2014*

However, whilst these figures are good to see, a growing percentage of the industry is aware of BIM but is still waiting to take the plunge. Investment costs are still a barrier and concerns remain over the likely returns. Despite the launch of new UK BIM protocols and guidance from the Government, many within the industry also remain confused by the subject and maintain a lack of trust in the claims of what BIM can deliver. This is balanced by the positive comments of those who have delivered projects using BIM and who can demonstrate returns on investment. There is still a real need for training and development that can articulate the reality of BIM, where it needs to go by 2016 and the development of Level 3. Despite this caution, the UK is recognised around the world as leading the agenda for improving efficient and effective construction information and implementing BIM.

- **BIM IN AUSTRALIA AND NEW ZEALAND**

Australia and New Zealand are both trying to reach the list of counties in the next tier of BIM maturity. Although, BIM has been introduced in that region not long ago but the market has quickly recognised its value and actively involved in developing skills for successful BIM adoption. According to McGraw-Hill Construction (2014), more than 51% are engaged in BIM on more than 30% of projects today and these numbers are expected to increase dramatically in the coming years, as over 74 percent of surveyed firms suggested they will engage in BIM in over 30 per cent of their projects in the next two years.

- **BIM IN HONG KONG**

Hong Kong is another example of early BIM adopters, as The Hong Kong Housing Authority (HKHA) is driving the BIM implementation agenda since 2006 for BIM enabled design, sustainability studies and construction coordination of its public housing projects. The BIM initiative follows the regulatory policy of the Works Branch of the Development Bureau of Hong Kong towards BIM. A BIM centre was set up in 2009 at the headquarters of the HKHA to promote the use of BIM and facilitate experience sharing. HKHA has been piloting the use of BIM in new public housing projects since 2006. Its experience with BIM suggests that BIM can improve productivity and efficiency in terms of enhancing collaboration, design optimization, construction planning and conflict detection. HKHA anticipates it will save time and cost, with less wastage in the long run, (Wong et al., 2010).

HKHA will continue to use BIM in more projects, with an aim to cover all projects from 2014/15 onwards. To develop BIM as a more user-friendly tool in Hong Kong however, HKHA plans to explore more application areas, for example, automatic extraction of bill of quantities from BIM models, checking of building codes to comply with building regulations, integration with specification, prefabrication and assembly RFID, etc. HKHA considers that the requirement for BIM in the AEC job market would soon change from being a ‘desired skill’ to a ‘required skill’, (Wong et al., 2011).

In summary, BIM has become a global phenomenon and more countries are making commitments to adopt BIM all round the world. In South Korea, The Public Procurement Service made BIM compulsory for all projects over S\$50 million and for all public-sector projects by 2016. More recently, the EU parliament voted in favour of encouraging BIM adoption in its 28 member states measures, (CIOB, 2014). As the benefits and value of BIM is becoming more evident, large clients and Governments are encouraging BIM adoption to reduce capital investments and get high quality construction projects.

### **3.3 BIM IN THE GCC**

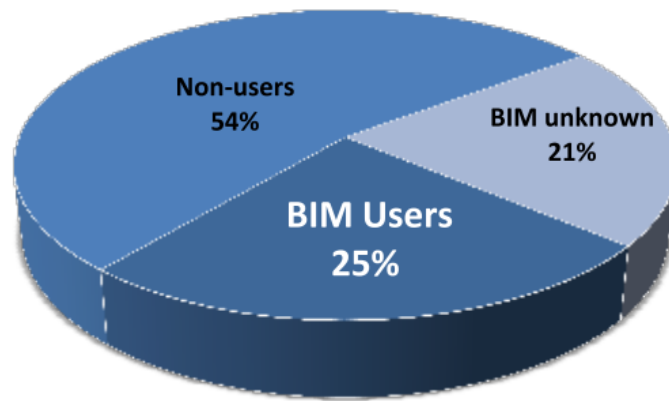
In parallel, a number of other countries have also shown strong interest in BIM adoption, especially in the GCC region. Many countries have already utilized BIM on a number of projects and successful results have encouraged Government and clients to create more demand for BIM within their markets. Strong presence of BIM can be seen in KSA, UAE, Qatar, Brazil, Egypt, India, and Pakistan, (McGraw-Hill Construction, 2014). The author has been personally involved in a research project (MSc thesis research) with Saudi Engineering council, involving over 400 construction professional

in Saudi Arabia. The research results confirmed a strong demand for BIM and highlighted a number of issues indicating a struggling market to adopt BIM. The following sections are presenting a brief outlook of BIM adoption in some of the developing countries.

- **BIM IN THE UAE**

The construction and real estate industries in the UAE are on a boom from last 15 years. It is reported by Deloitte (2014) that the UAE's construction market is to grow at the rate of 5.1% annually until 2016, where construction contracts to build infrastructure and housing projects may exceed 30 billion USD. Dubai in particular is already experiencing a surge in the number of new government-led infrastructure developments and the recommencement of work on stalled projects, technology can play a huge role in creating, managing and executing projects of such scale and size. This huge size of construction projects, and deadline to match upcoming events (e.g. Expo 2020), demand latest technology solutions and delivery methods that can save cost, reduce time and result in high quality projects, and thus use of BIM become inevitable in this context. This is already realised in the UAE, as Dubai municipality has already mandated the use of BIM in November 2013 on their public-sector projects. A survey by buildingSMART-ME showed that BIM users in the UAE were about 25% (see figure 3.7), which is increasing with increasing client demand and market awareness.

## BIM Usage in GCC & Jordan



**Figure 3.7: BIM users and non-users in the UAE**

*Source: (Baldwin, 2013)*

Dubai Municipality has decided to mandate the use of BIM for architectural and MEP works for all buildings 40 stories or higher; facilities/buildings that are 300,000 sqft or larger; all hospitals, universities and other similarly specialized buildings, and all buildings that are being delivered by/through an international party. The announcement also states that the decision to mandate BIM is based on the (proven) ability of BIM tools and workflows in improving construction quality, enabling collaboration between project participants across project phases, lowering cost and reducing time, (Deloitte, 2014). Similarly, Abu Dhabi and Al-Ain governments are strongly backing up BIM adoption, with local universities playing a vital role in educating the industry about the BIM enabled working, (Gomez, 2013). Some examples of BIM enabled projects in the UAE are presented in the figure 3.8.





**Figure 3.8: Example projects of BIM use in the UAE**

*Source: (Baldwin, 2013)*

- **BIM IN QATAR**

Qatar has already made commitment to build FIFA World cup 2022 stadiums and infrastructure using BIM to leverage the cost and time to achieve the ambitious schedule of the projects. Qatar is on a verge of change in its infrastructure and economic outlook of the construction industry, due to various mega projects towards vision 2030. From Doha's Metro System to the numerous sporting stadiums (See figure 3.9), BIM will enable project teams of architects, engineers, building and infrastructure owners and construction firms to use 3D digital models to collaborate and support building projects throughout their lifecycle - from design and documentation to building and field support - ensuring that projects are delivered to the required specifications on schedule and within budget, (QNCC, 2014a).



**Figure 3.9: Doha Metro projects-BIM in Qatar**

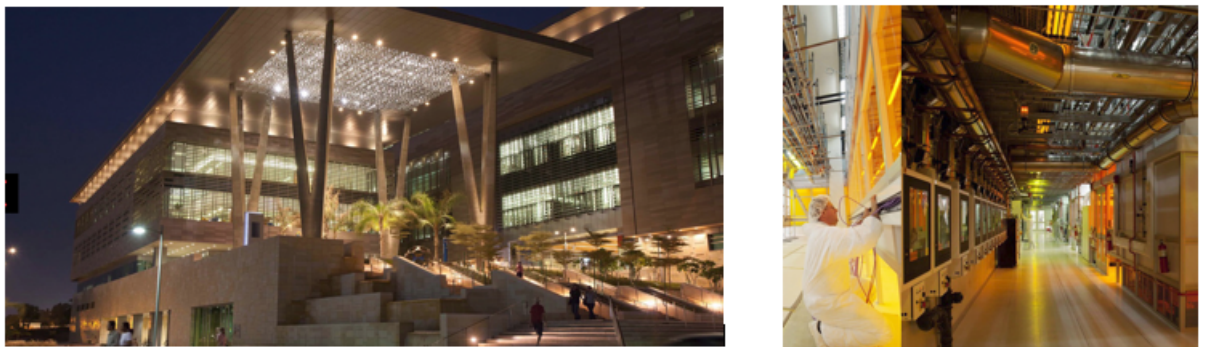
*Source: (Deloitte, 2014)*

Qatar's railway network project will see a US\$35B investment that includes plans to extend Qatar's railways by 325 kilometers, and its rail networks to those of other GCC countries, (Deloitte, 2014). If the use of BIM can save 5% to 10% of total contract cost on such projects, then it would be a very significant achievement. In addition to FIFA World Cup 2022 and Doha Metro projects, Ashghal-Doha expressways and Lusail REDC-Lusail City projects are also using BIM technology and a collaborative working project delivery methods, (Gomez, 2013).

BIM adoption in Qatar is only to grow, as the future BIM Implementation Qatar is the essential platform in 2015 for all those involved in the architecture, design, construction, engineering, consulting, building and infrastructure industry in Qatar and the GCC to stay up-to-date on how this software and technology is facilitating future cities in the region, (QNCC, 2014b).

- **BIM IN THE KSA**

The first notable BIM project in KSA was taken on the construction of King Abdullah University of Science and Technology in 2007, which is still a landmark project in the region for exceptional demonstration of BIM management, (BuildingSMART-ME, 2011).



**Figure 3.10: KFUST-Example of BIM project in KSA**

*Source: (BuildingSMART-ME, 2011)*

On this project, (Figure 3.10) an integrated project team consisting of the client (Saudi Aramco), Consultant (HOK) and contractor (Saudi Oger) employed the BIM form concept design to project completing, reporting the benefits on project as:

- Reduction in CO<sub>2</sub> emissions and improved design facilitating renewable energy sources.
- Reduction in overall energy costs by 24.5%.
- 70% recycling of construction waste.
- Visualization power of BIM helped to preserve natural habitat.
- Enhanced use of local materials and off-site manufacturing opportunities.

- Project was completed on time due to improved collaboration and accuracy (Sharif, 2012).

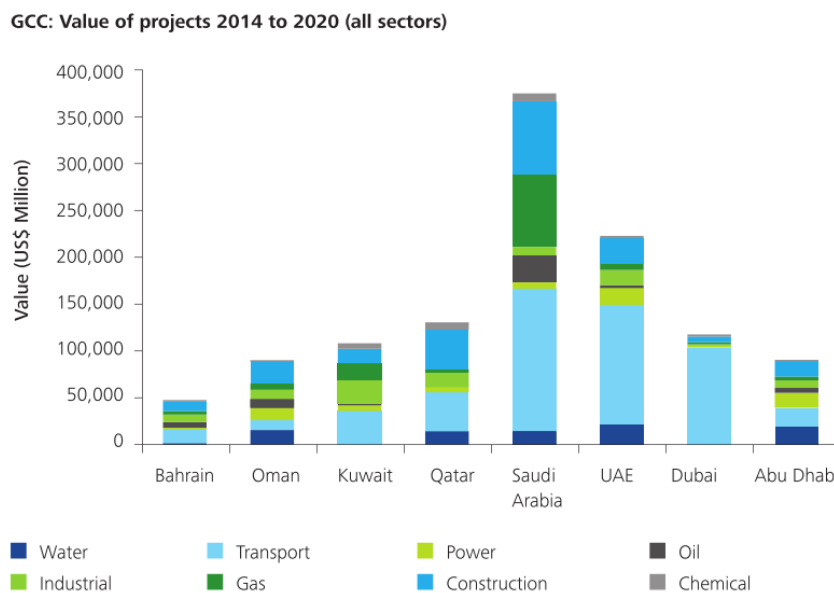
Since then, the KSA government is strongly encouraging the use of BIM in the region, and it is expected that the BIM capabilities of construction companies will play a vital role in winning them work in public sector project within the Kingdom, (Sharif, 2012). Large and multinational construction companies operating in KSA already has a BIM base and they can also afford to outsource BIM services to gain competitive advantage, (BuildingSMART-ME, 2011).

### **3.4 KSA CONSTRUCTION INDUSTRY**

The construction industry in Kingdom of Saudi Arabia (KSA) is experiencing large scale investments by the KSA government in construction and real estate sectors, which constitutes about 40% of its oil driven economy. These heavy investments in infrastructure and urban development projects started in last decades, such as from 1990-2000 an investment of 234 billion USD were made towards construction projects (Albogamy et al., 2013). This boom in the construction industry in KSA is still on a raise, as the KSA is leading the way in the GCC region with over 1 trillion USD projects, either planned or underway between 2010 to 2020 (Corby, 2014). From this, the residential sector in the KSA accounts for under 30% of that market spend, while healthcare at 20% and education at 10%, which shows that the spending in the development of social infrastructure is still a priority in the KSA, (Deloitte, 2014). In last three years, the highest value project contracts were awarded in transport sector, especially for rail and aviation projects, for example the King Abdulaziz International Airport in Jeddah and Riyadh Metro projects. This trend will further continue in the five

years, as a new contacts has been awarded for Saudi Landbridge rail project (7 billion USD) and expansion of Riyadh's King Khalid International Airport (10 billion USD), (Corby, 2014).

In Addition to spending in the infrastructure projects, the KSA also needs new residential projects for the growing population that is quadrupled over last 40 years. The late King Abdullah bin Abdulaziz Al-Saud announced in March 2011 that the KSA government will invest 70 billion USD in building new homes for the Saudi national in next five years (Deloitte, 2014). This was followed by the Saudi Ministry of housing that commissioned 1.1 billion USD for new homes in seven cities of KSA including Tabuk, Jeddah and Dammam as part of the King's pledge to create 500,000 new homes for Saudi national (Deloitte, 2014). Although, the whole GCC region is going through a government investment-led development but KSA is leading the way by far in construction and real estate development sectors, as reflected in figure 3.11.



**Figure 3.11: KSA is leading the construction & real estate development in the GCC**

*Source: MEED, 2014*

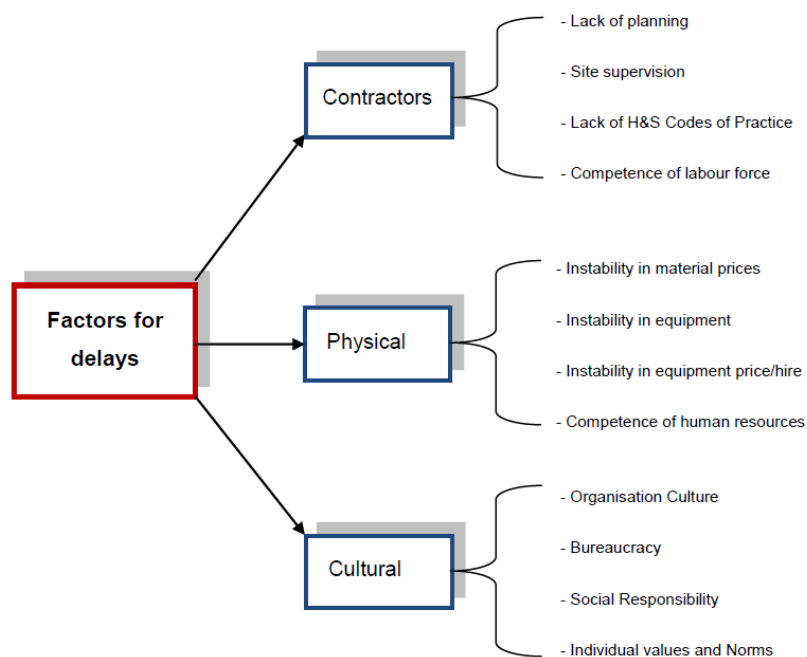
This massive scale of construction in the KSA, started about 2 decades ago and is still on a rise, has created cost inflation and lack of availability of project resources which result is project delay, poor quality and unsatisfied clients. The next session discusses the core problems of the KSA construction industry.

### **3.5 PROBLEMS IN KSA CONSTRUCTION INDUSTRY**

Traditionally, the KSA construction industry is dependent on imported machinery, equipment, materials and manpower for all kind of construction operations. The local cement industries are already operating all full capacity and yet these are not able to match the requirements of the market, resulting in more dependency on imports. The availability of labour force (generally imported from India, Pakistan, Nepal, Philippines), and skilled construction professionals is becoming difficult due to the large scale of construction projects. The introduction of Saudization Program, which requires a certain percentage of local national's employments in a company, has been enforced last, which could lead over 2 million expat workers to leave the KSA (Surf & Saied, 2014). These factors have unfavourable effect on the construction industry in KSA due to shortage of unskilled local labour and through higher input costs (Corby, 2014). In summary, the huge investments, changing legislations and increasing competition in the construction market have added tremendous pressure on the construction industry in the KSA to improvise and improve its practice.

It is evident of the literature review that the main problem of the KSA construction is project delays and poor productivity, which is attributed to a number of factors, such as adverse weather conditions, remote nature of projects, unavailability of skilled staff, poor planning practices, inefficient use of resources and changing government

regulations and requirements (Albogamy et al., 2013; Al-Kharashi & Skitmore, 2009; Jarkas & Bitar, 2012; Mahamid & Aichouni, 2013). It was reported by Al-Kharashi & Skitmore (2009) that delayed projects accounted for over 70% of public projects by the Ministry of Housing and Public Works. The delay of any construction project is a direct result of poor planning and productivity which seriously affect project cost, Alotaiba (2011) has reflected lack of planning as a key reason for poor site productivity from contractors that causes project delays, see figure 3.12.



**Figure 3.12: Main delay factors in KSA construction industry**

*Source: (Alotaibi, 2011)*

As mentioned before, a key characteristic of KSA construction industry is the social-cultural characteristics due to its dependencies on expat workforce. The construction workforce comes from different backgrounds, as there is large number of labours from South Asian countries, engineering managers from Europeans & Americans and company owners & CEOs consist of KSA national. This cultural diversity lead to

complex organisational structures, create communication problems that ultimately affect the performance and productivity. In addition to that, Alotaibi (2011) argued that the lack of equipment and its maintenance as one of the influential factors in public construction projects in KSA. He also stated that a large number of projects experienced delay, especially in medium and large size projects. Al-Ghafly, (2008) also identified project owner involvement, contractor performance and the early design and planning of the project as the key factors for project delay in KSA. (Sidawi, 2012) indicated contractor performance as one of the major causes of delay in projects in KSA.

In summary, due to such a construction boom, demand is high for construction equipment, materials, technology and efficient construction management, including managerial techniques and methods of operation. All in all, the construction industry in Saudi Arabia faces a number of real challenges; some are unique to the environment, while others are inherent in any construction business. Owners share three primary concerns: cost, quality and time of completion. These challenges are compounded by the traditional 'sequential' approach to construction. Indeed, many previous studies report that the industry faces chronic problems such as delay, low productivity, poor quality, waste, mistakes and rework. One of the most critical problems in the government sector is the frequent and lengthy delays in completing projects (Alotaibi, 2011; Mahamid & Aichouni, 2013, Albogamy et al., 2013; AlSehaimi, Fazenda, & Koskela, 2013).

### **3.6 POTENTIAL OF USING BIM IN KSA**

Construction has often been a major driver of growth, reflecting both the demographically driven need for housing, which is subsidised, and efforts to build a



modern infrastructure. To cope with all these trends, the government has undertaken ambitious initiatives to improve the existing departments within public bodies, so that they will be able to control various construction activities, mainly projects financed by the government in the fields of education, health, infrastructure, public services and state buildings. The government has also ordered the expansion of certain bodies and the establishment of new specialized construction control units in order to improve quality and completion time of construction projects, (AlSehaimi et al., 2013).

Since the use of Building Information Modelling (BIM) is growing worldwide (chapter 4) and has a proven track record to bring improvements in construction project, reduce cost, improve quality and delivery better projects to clients. The KSA government is favouring the use of BIM on large scale projects in the KSA, as only a 5% decrease in project cost in KSA can save millions of dollars in a single project due to the large scale of projects in the KSA. Some perceived benefits of BIM that can bring productivity improvements for all stakeholders in the KSA construction industry are discussed in the following sub sections:

- **Perceived BIM uses for KSA construction industry**

Although a detailed discussion on BIM uses and benefits is presented in the earlier chapters, section particularly discuss some of the BIM benefits in the background of KSA construction industry and how these BIM uses can resolve inherent problems of the KSA construction industry.

- **BIM as a powerful visualization tool**

BIM is a very powerful visualization tools that can create photorealistic visualizations and animated simulations of the proposed design solution which can be extremely

helpful in understanding and communicating design intent to other project stakeholders, (Isikdag, 2012). Construction clients are often unsatisfied with the finished product which is due to the fact most of the clients fail to understand the design in 2D and therefore feel unhappy with the delivered product. Visualization is an effective tool to communicate the understanding of design and final look of finished product early in the project which will reduce the number of change orders by the client and will result in more satisfied clients, (Bryde et al., 2013). For contractors, visualization aspect of BIM can be used to create 3D models, animated walkthroughs and sequencing of project components at bidding stage as it acts as a competitive advantage in winning new work, (Hardin, 2009). Moreover, visualization and simulation of project components also help project teams internally to collaborate and optimise the construction process. Contractors can simulate construction activities in a 4D environment and foresee the construction sequencing along with required resources. Simulations in 4D also help reduce number of accidents on site as health and safety analysis can be better performed with visualization aspects of BIM, (Cifuentes, 2012).

Some projects in the KSA have already used BIM and strong visualization with BIM models has added valuable contribution to project success. For example on the AL-Yasmine project in the KSA, BIM visualization was used in conceptual messaging, presentation of various design options to the client, 3D model navigation of final design, and inters disciplinary simulations analysis for coordination among consultants and contractors, (Cifuentes, 2012).



**Figure 3.13: BIM enabled visualization in AL-Yasmine project in the KSA**

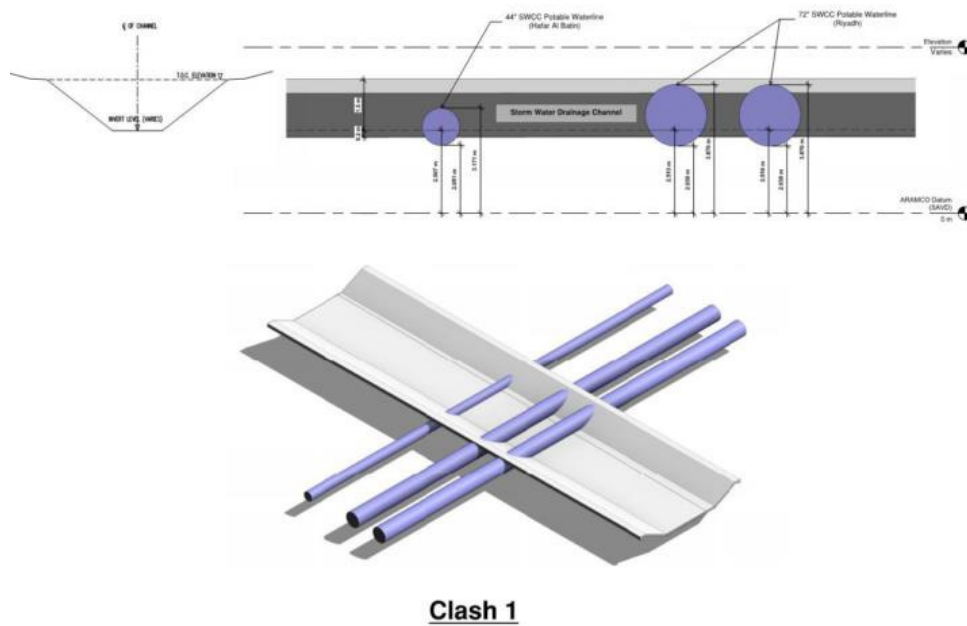
*Source: (Cifuentes, 2012)*

In short, powerful visualization of project information using a 3D BIM model can bring productivity improvement in a number of areas for all stakeholders in a construction project, therefore, it can be extremely beneficial for the KSA construction industry.

- **3D coordination and clash detection**

3D coordination of building information and clash detection in the design phase are perhaps the most valuable use of BIM, not only for designer but also for contractors and ultimately for project owners (Brief et al., 2008). Project teams can coordinate in 3D with BIM models (e.g. architectural model, structural model, MEP model) in order to find clashes in design and resolve them early in the project. This could save a lot of rework and cost as any clash detected during construction costs a lot more time and resources to fix. The project team can start 3D coordination as soon as the project grid and space planning is complete. Architectural and structural models are coordinated to check the clashes in spaces and structural elements positioning and any conflicts are resolved early in the design process. MEP model and information from fabricators can

be used to check the clashes of duct work and other building elements, (Hooper & Ekholm, 2010). An example of 3D clash detection with BIM is shown in the figure 3.14.



**Figure 3.14: Clash detection with BIM on AL-Yasmine project in the KSA**

*Source: (Cifuentes, 2012)*

As discussed in the above sections that a major cause of project delays and low productivity in the KSA construction industry is the rework and errors in design that cause serious implications for time and money as well as the project resources. Therefore, 3D clash detection and coordination has significantly reduced such errors during the design stage and will improve the productivity by a great margin in the construction stage.

#### ▪ **Prefabrication**

Prefabrication or offsite construction of building elements is widely acknowledged as a cost effective and time saving method in construction execution process, (NBS, 2013). Prefabrication provides opportunities for the manufacturing of accurate and high quality

elements in a controlled environment away from jobsite, which can result in more reliable and cost effective construction solutions, (McGraw-Hill, 2012). An accurate and validated BIM model can facilitate the fabricators to automate the fabrication process as it will save rework, but the information exchanged must be interpretable as fabricators might be using different software than the native BIM format provided with the contractor, (Hergunsel, 2011). Another powerful aspect of BIM enabled prefabrication is the application of “lean construction” as the contractor or construction manager can simulate the production activities to accurately predict the assembly line of components and hence a detailed procurement of product and delivery schedule can be managed with the “just in time” approach, (Arayici et al., 2011). In addition to that, numerous other opportunities with BIM enabled prefabrication are possible in offsite production of building components, for example, offsite manufacturing of casework installers, pipe production coordinated cut length with built-in space for hot and cold water as per project specifications etc. BIM applications in prefabrication is not limited to coordinate location and routing of the products but it can also be used to automate the offsite production process, (Hergunsel, 2011). However, this would require involvement of supply chain and trade contractors in the BIM process in order to truly realize the full benefits of virtual design and construction.

In the KSA, weather conditions are extremely difficult for on-site execution activities during day times; therefore, BIM enabled prefabrication can save a lot of valuable time and resources during project execution. The construction of King Abdullah University of Science and Technology (KAUST) was a landmark project for BIM use in the KSA, which has used BIM enabled offsite construction and reported healthy improvement in productivity. According to the project manager of KAUST “Having the BIM on site during construction gave us an accurate and interactive 3D reference to our figure tips;

this becomes an invaluable tool for quality assurance, detection and elimination of any onsite errors”, (BuildingSMART-ME, 2011).

- **Construction Planning and Monitoring (4D)**

In a BIM enabled project delivery, scheduling and sequencing of project tasks are coordinated with BIM models in line with time, space and project resources. Traditional project plan (e.g. Primavera or MS Project plan) can be linked with model components adding time dimension into 3D model, which is called 4D modeling. 4D models can be created by using various BIM tools, for example Autodesk Naviswork Manage or Synchro professional, which can create 4D model simulation of construction activities based on Critical Path method (CPM) or line of balance as adopted in the planning of construction tasks, (Hergunsel, 2011). 4D models can be used to communicate construction sequencing in a simulated environment which greatly enhances the utilization of site resources, space utilization, procurement of equipment and material, management of manpower, health and safety planning and collaboration with vendors and sub-contractors, (Brief et al., 2008). 4D models can be used to foresee traffic access routes during execution periods, positioning of temporary structures and moveable machinery (e.g. Trucks, cranes, excavators etc). Site logistics planning with 4D models create opportunities to implement a “just in time” approach for material and manpower handling which results in waste reduction, cost saving and effective use of project resources, (Kymmell, 2008). An example of a 4D model is presented in the figure 3.15.



**Figure 3.15: Use of 4D model for schedule simulations**

Another key use of BIM enabled project planning is the identification of safety features that will be required during the handling and installing of various project components on the jobsite. 4D visualizations can be used to model temporary structures (e.g. rails, fences) which can integrate with schedules to foresee the performance of difficult tasks and operations during task execution. For example, all the activities related to installation of lifts can be modeled in a 4D environment and simulation will show the sequencing of activities to installation works in order to remove any surprise activities ensuring that they understand the process well, avoiding any accidents on site. In short, the planning and monitoring of a project is an extremely important task for contractors which can be better performed with use of BIM enabled 4D modeling and associated technologies.

This is highlighted in the previous section that the KSA construction industry is heavily critiqued for its poor planning practices that is a major cause of project delays. Therefore, the application of 4D modelling can revolutionized the project planning and

monitoring practices in the KSA construction industry, which can result in significant productivity gains on projects.

- **Cost Estimation and management (5D)**

BIM can be used to automatically extract quantities of the modeled elements which can be downloaded in a cost database or excel file reducing the risk of possible calculation error, (Hooper & Ekholm, 2010). Quantity estimators have been performing the laborious job of different formula application for quantity take off, which can be automatically performed with a BIM model. In addition to that automated quantity takes off can help in cost planning as any iteration in cost change or design change can be automatically calculated and communicated. The cost estimation can be modeled into 4D models to produce a 5D model which will have costing and budging information added to the project schedule. Project teams can view the cost information of individual items, a group of elements (e.g. all doors), a specific area in project or the overall project cost. Associated costs with any change in design can be reflected in a 5D model which is extremely useful to communicate the ripple effect of a design change to lay people, (Underwood & Isikdag, 2009). Contactors can use 5D models to build an in house database of costing information, productivity rates, provide cost loaded proposal in bid for a competitive advantage and provide iterative costing estimates for the owner during the execution process.

In a large-scale construction market, such as the KSA construction industry, the use of BIM enabled cost estimation and management can be very useful, not only in terms of accurate generation of BOQs but also adding a competitive advantage for work winning.



- **Record Model/As Built Model**

A well acknowledged use of BIM is for facility management as the owner of a project can use accurate information in a BIM model for the operation and maintenance of the built asset, (East, 2007). Construction managers or the contractor can provide the owner with a record of the BIM model with all the necessary information as the built information at the handover phase of a project. This record model contains information from manufacturers and sub contractors about the performance of installed equipment, including links to submits, warranty information, insurance information and maintenance manuals. This record model also acts as a database for security related information (e.g. emergency exits, pathways, positioning of fire safety equipment like fire alarms, sprinkler systems etc), (Hergunsel, 2011). The facility manager can use the built in information in the model to plan for energy consumption of building operations. In addition, the positioning of furniture, equipment, MEP installations can be tracked in the record model which can enhance the planning and execution of any renovation or refurbishment tasks later on in the project life cycle. Information in the record model is useable in predicting operational costs and managing cost impact for renovation and maintenance tasks. The use of BIM for facility management has encouraged the project owners to prefer BIM implementation on project which is a potential advantage for BIM expert contractors. The efficiency of a contractor in providing a record model to the owner can leave long lasting advantages to impress the facility owner, which could result in future business relationships (East, 2007). Clients are already asking for facility management ready BIM models from contractors in other Middle Eastern countries (e.g.UAE, Qatar), which will soon become a requirement in the KSA as well, (Gomez, 2013).

The KSA government is the largest construction client with trillions of dollars built assets all around the country. A BIM enabled facility management can significantly improve the operation and management, which can be a real driver for the KSA government to mandate the use of BIM.

### **3.7 SUMMARY**

This chapter has reviewed BIM adoption and implementation in different countries of the world, reflecting that BIM has been well established and growing even more. The chapter reflects that early adopters of BIM, such as USA, Scandinavian countries, UK, Singapore and Hong Kong, are practicing BIM enabled working from more than 10 years and still trying to increase industry wide adoption through mandatory BIM requirements and government supported policy guidelines. On the other hand, the GCC countries experiencing a rapid growth in the construction markets are looking to adopt BIM but their BIM implementation efforts are not in harmony with the policy guidelines or government support. A number of BIM enabled projects are already completed or planned in the UAE, QATAR and KSA, and BIM adoption is going to increase more in these countries.

This chapter has particularly highlighted that the KSA construction industry can benefit from a range of BIM applications that can improve various aspects of construction productivity in the KSA. However, in such a volatile construction market like KSA, this is not achievable at once, rather it would take a very strategic approach to plan for short term and long terms BIM implementation strategies to capitalise the true potentials of BIM for any productivity improvement. The BIM benefits like 3D model visualization and simulations can be achieved in a short time if trained staff are available in BIM

applications and therefore, instant productivity improvement can be realized in design stage. The use of BIM for on field supervision, site logistic planning and construction sequencing can be considered as medium-term BIM benefits as they require some degree of expertise in multiple BIM tools and little support from the supply chain. In the KSA, client interests are growing towards prefabrication due to adverse weather conditions. A BIM driven prefabrication practice may be considered as a long term long productivity improvement tools as it would require a more mature supply chain in BIM implementation.

It is evident from the above sections that BIM in the GCC, including KSA, is experiencing a rapid but uncontrolled demand, driven by the large scale of construction project in this region. Despite this huge demand, there is little awareness in the market as construction companies (consultants & contractors) in this region are relatively immature in use of advance technologies and more resistant to change. Moreover, BIM implementation in the KSA is heavily based on mere use of technology with no emphasis on strategy or process which is essential to bring any significant productivity improvement with BIM implementation. Following conclusions can be drawn from this,

- There is growing but uncontrolled demand for BIM in the KSA
- Governments and owners showing interest in BIM
- Contractors & Consultants seeking to quickly adopt BIM, due to market demand and presence of multi nationals to stay in market competition.
- Technology driven BIM; little emphasis on strategy, process or Standards
- No clear guidance or regulations.

While the developing countries are catching up with BIM, they have one advantage that is to learn from the experiences for earlier BIM adopters. A lot of BIM guides,

protocols and standards have emerged during the course of BIM adoption in developed countries (“BIM Project Execution Planning Guide, 2010; BIMTaskGroup, 2013; NBS, 2013; PAS 1192-2:2013, 2013), that can be used as acknowledge resource to adopt and tailor according to the regional requirements to facilitate BIM implementation, such as in the KSA. At the moment, the BIM market in the KSA is flooded with a lot of confusion and concerns about BIM implementation, which generally as a result of “so called BIM Experts” in the region, over selling their capabilities of pure technology (BIM software skills) having very little understanding of process, and nature of collaborative working that is basic requirement to make BIM work for any market. Therefore, there is strong need to evaluate the local conditions of the KSA construction market and exemplars of BIM implementation in local environment to reflect real world facts about BIM implementation in the KSA. This will help the local industry to understand the true value of BIM and what productivity improvement can actually be archived with BIM uses in the region. In addition, creating a strong business case for BIM is critical with statistical evidence to show productivity improvements and return of investment on BIM projects.

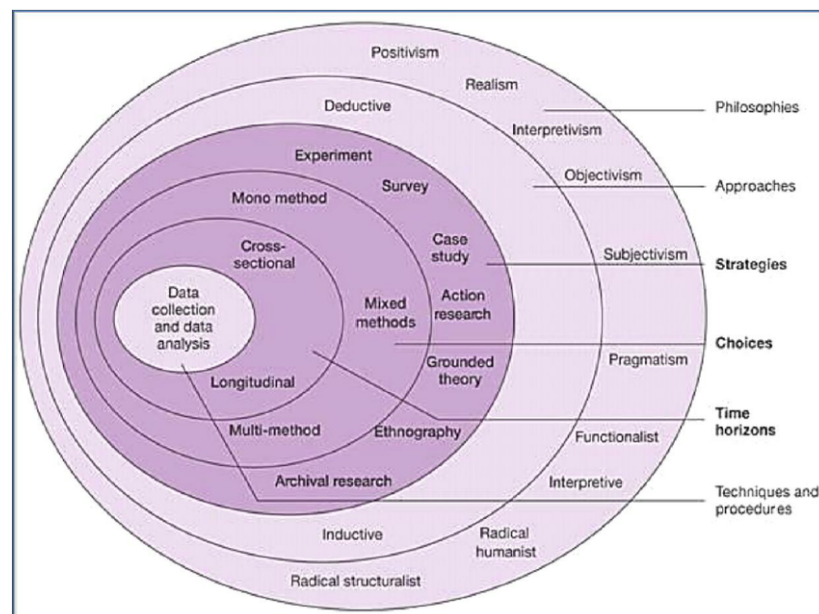
In summary, the applications of BIM can resolve the inherent problems of the KSA construction industry and can improve the productivity in the project delivery process. But BIM is not a fancy use of technology but a collaborative work process that involved several complexities, both at project level and at organizational level BIM adoption. So, it raises questions related to finance and resource commitments for the companies making a move towards BIM adoption, especially in the markets like KSA which are heavily depended on expats and external technical resources. Generally, the metrics to measure the productivity improvement and ROI on BIM has been cost reduction, waste reduction, energy efficiency, sustainable design and production, carbon footprint

reduction, lesser RFIs, fewer unplanned changes, higher customer satisfaction and less disruption in project process, (Chelson, 2010; McGraw-Hill Construction, 2014). It is noted from the literature that the metrics to measure productivity and return of investment are region specific and it can differ greatly depending upon the circumstances of a market. For example, energy consumption and carbon footprint reduction are on top of agenda in the UK due to legislations and high energy costs, where these metrics are not important in the KSA construction market because of oil driven economy and cheaper energy costs. There are no studies investigating the particular aspects of productivity improvements with BIM application, reflecting upon local BIM experiences and case studies in the KSA or even in the GCC. This suggests a gap in the existing knowledge and this research aims to address this. The problem being addressed in this research is the need to investigate metrics for productivity improvements with BIM applications and return on investment in the particular context of the KSA construction industry.

# CHAPTER 4 : METHODOLOGY AND DESIGN OF THE FIELD STUDY

## 4.1 INTRODUCTION

This chapter constitutes the overall research methodology. Key research concepts such as research philosophy, research approach, research strategies and methods are discussed and justified for this research. The data analysis tools and ethical considerations are also discussed. Previous literature is explored to lay a foundation for this research and to justify the chosen methods, philosophies and strategies. The research onion developed by Saunders et al. (2012) is used as a structure for this chapter from the outer layer of the onion to the inner layer.



**Figure 4.1: Research onion**

*Source: Saunders et al., 2012*

## **4.2 RESEARCH PHILOSOPHIES**

A research philosophy is defined as the way through which the data, about an issue or phenomenon, should be collected, used and analysed to extract conclusions. There are a number of research philosophies which have been developed on the basis of two approaches i.e. doxology (what is regarded as a truth) and epistemology (what is known to be true) (Denscombe, 2010). The term is related to the nature and development of the knowledge. A research is largely the process of development of the knowledge and research philosophy provides it the right direction in a particular field (Avolio, 2009). A research philosophy is comprised of the pertinent assumptions about the processing of the collected knowledge and its analysis in the development of new knowledge, in form of concrete conclusions. These assumptions are involved in the selection of the research methods and strategy, as a developmental unit. In the field of management and business, a researcher needs to be highly aware and flawlessly clear about the adopted philosophy. It does not only impact the way of conducting research, significantly, but also helps in understanding what is going to be investigated in a research (Balvanes & Caputi, 2001).

The selection of a research philosophy must be done on the basis of practical considerations i.e. a practical view of the linkage between the process and the knowledge. Additionally, it is not only important that how much a research is philosophically informed, but also how well a researcher is able to reflect upon a philosophical choice, in regard to other alternatives available (Benbasat, 1981). The selection of a research philosophy is greatly dependent on the research questions, which hardly fall under the domain of any one research philosophy. In order to understand the best suited research philosophy, it is needed to get knowledge about available research philosophies and their suitability to the research questions and objectives. The research

philosophy depends upon two thinking processes i.e. epistemology and doxology (Brown, 2013). The certain differences in these two approaches significantly influence the way of conducting research. Following section includes the brief introduction of various research philosophies which have been developed over time in the domains of acceptable knowledge.

#### **4.2.1 PRAGMATISM**

As mentioned above, there are different thinking approaches about the research philosophy such as epistemology, ontology and oxology etc. These approaches check the suitability of a research philosophy choice to the conduct of a research. Pragmatism states that the major determinant of any thinking approach about the selection research philosophy must incorporate the research questions (Clark, 1997). Pragmatism is highly intuitive approach to conduct a research as it largely deals and directly connected to the research questions. It helps a researcher to avoid the unnecessary engaging issues and pointless debates about the concepts of reality and truth. Pragmatism comes under epistemology and doxology if there is not a clear announcement of being positivist or interpretivist (Cormack, 2000).

**Interpretivism:** The world of business and management is far too complex and cannot be restricted to generalisable ‘laws’. Hence, it is necessary to take into account the key differences and variations. Interpretivist approach stresses a researcher to identify, explore and understand differences between humans as social actors (Creswell, 2002). This emphasises the conduct of a research among human beings, instead of objects such as computers or trucks. This philosophical approach directs a researcher to enter into the social world of subjects and to understand their views in order to collect real term data.



This approach is highly suitable and practically applicable in the fields of management and business research. It helps in exploration of complex and unique situations which are an important aspect of business world (Ritchie & Lewis, 2003).

**Subjectivism:** Subjectivism comes under the section of ontology. It relates to the view that a social phenomenon is a creation of consequent actions and perceptions of social actors. More importantly, it is continual process. As a result, the creation of social phenomena remains in a constant state of revision. In a research, Remenyi et al (1999) argues that it is pertinent to comprehend the details of a situation to understand the reality working behind it. It is, then, associated to the word “social constructionism or constructionism”. It stresses the exploration of subjective meaning of social actors so that a researcher could be able to understand the actions of social actors (DeBoer, 2014). Subjectivism defines the reality of research as being socially constructed. In simple words, subjectivism deals with the real ground on which a research should be conducted. It stresses a researcher to understand and explore the underlying concepts, ideas and theories of an issue which is going to be studied. Subjectivism is different from objectivism and it can be clear by this example that objectivism views an organization by the culture which it has. In contrast, subjectivism views an organisation by what it really is, on the basis of its social enactment (Gall, 1996).

**Realism:** Realism relates to the scientific enquiry that the objects are independent of the effects of human minds and our senses show us reality as a truth. Realism is a scientific approach to the processing and development of knowledge (Saunders, et al., 2009). It has two main types. First type, direct realism, states that what our senses tell us, is the real portrayal of world. Second type, critical realism, states that our experiences are the images of the real things in the world, not real things directly. In short, realism depends

on the senses of a researcher, his views, his experiences and concepts about the research which, then, will be analysed to yield the generalized conclusions (Creswell, 2013). During this, a researcher has real- time experiences with the world in order to collect data such as surveys, interviews and case- studies.

**Positivism:** In this approach, a research follows the stance of natural scientist. The research may start with an observable, social reality and may end with generalisable conclusions. The resources for such type of research need the collection of data and production of credible data. A researcher is needed to follow a particular research strategy, data collection method and an existing theory. In this research philosophy, hypotheses are developed and tested (Crossan, 2003). This philosophy is more applicable in laboratory based scientific research, as it is objective in nature.

**Objectivism:** Objectivism comes under section of ontology which concerns about the nature of reality. It is concerned with the assumptions which a researcher makes the commitment to particular views. Objectivism addresses with the existence of social entities, external to the social actors. In the field of management, it inherits great importance as management itself can be regarded as an objective entity. In order to understand, it can be said that every organization follows a certain management structure which is objective to each organization. This structure includes the job description of managers, operating procedures, a formal structure or hierarchy and a reporting system (DeBoer, 2014). The essence of this management function is same; however, the structure could have slight changes or differ to each other. Hence, management in every organisation can be different but, it is a function of numerous objective aspects of management (Avolio, 2009).

#### **4.2.2 JUSTIFICATION FOR THE CHOSEN RESEARCH PHILOSOPHIES: REALISM AND INTERPRETIVISM**

Based on the comprehensive review of the research philosophies, the chosen philosophies are realism and interpretivism. Many exploratory and descriptive researches have been done on the implementation of Building Information Modelling (BIM). But, the critical point is to conduct a research on the practical implementation of BIM in the construction industry of Middle East and KSA region, particularly to gauge the persistent problems in the construction market (Balvanes & Caputi, 2001). Realism argues that there is a reality out there and this research will explore that reality (implementation of BIM in the Middle East including Saudi Arabia) and will respond to it. Hence, it is necessary to collect data which is particular to the Middle Eastern and Saudi construction market as well as which can grasp the nature of problems and their intensity in construction business. To know the reality of BIM applications, qualitative data will be collected and analysed through the research philosophy of realism. It will address the research objectives. Similarly, interpretivism allows the utilisation of qualitative data to conduct a research. Since, this research is being conducted to explore the real-world problems and propose solutions in the construction industry of KSA; it is needed to have a valid and reliable results. The results will be interpreted based on the research participants' opinions and perspectives.

#### **4.3 RESEARCH APPROACH**

Every research involves a theoretical approach on the basis of which, a research is conducted. It is needed to make it explicit in conclusion and findings. It is also necessary to be clear about the theory, prior to conduct a research. There are two main approaches which are being implemented by researchers in order to conduct a coherent and valid research in the field of business and management. These approaches include;

deductive approach and inductive approach. In deductive approach, a researcher develops a theory and hypotheses to test and analyse through the collected data in the research (Hightower, 2011). On the other hand, in inductive approach, a researcher collects data and develops theory, in consequent to the data analysis of this collected data. The following section explains the basis characteristics of these two approaches, their differences and consequent implications (Bryman, 2004). However, it is also argued that both research approaches can be combined and it is advantageous to do so (Denscombe, 2010).

On the other hand, inductive approach involves collection of data from an appropriate sample population, testing & analysis of the data, drawing conclusions and development of a theory or practical concept. The purpose of inductive approach is to introduce or develop a new theory, approach, concept or idea about what is going on. It is done to better understand the nature of an issue or problem (Hill, 1999). The formulation of theory is done on the basis of analysis of collected data in form of interviews or surveys.

Inductive processes let the researchers to find and understand cause- effect relationships between variables and concepts. Critiques of deductive approach include the sense of finality in terms of selection of theory and hypothesis (Hirschman, 1986). It sounds like deductive approaches have a tendency to develop a rigid method which does not allow alternative use of explanations. It does not help in understanding the nature of problem or what is going on. Another difference between deductive and inductive approach is the sample size. Inductive processes are conducted in specific contexts in order to deeply understand and evaluate the on- going events (Creswell, 2002). Hence, it is better to conduct a research with an inductive approach by studying a small number of

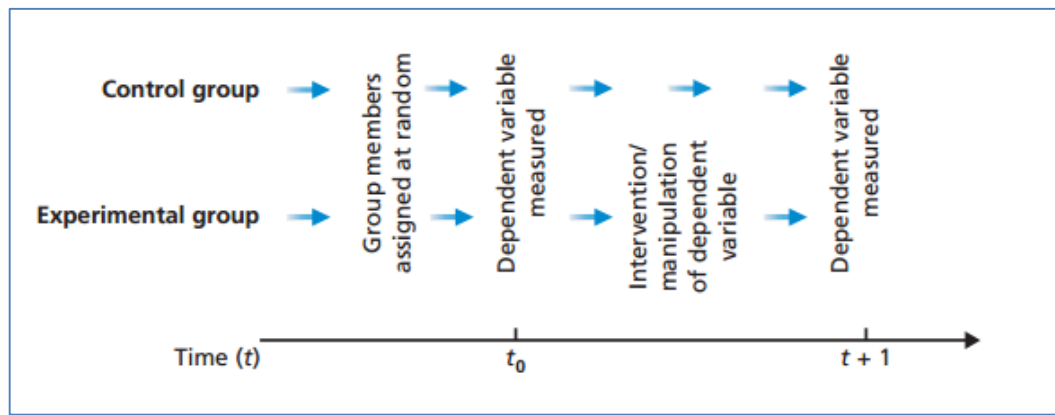
subjects. Commonly, researchers are used to review qualitative data and implement various methods to collect primary data in order to make a clear understanding of different views of a problem. In this research, inductive approach is used and interview were conducted to gather qualitative data.

#### **4.4 RESEARCH STRATEGY**

There are numerous research strategies which have been developed and used for descriptive, explanatory and exploratory researches. Some of these strategies fall under the deductive approach, while others are used for inductive approach. Each research strategy has its certain advantages as well as disadvantages (Benbasat, 1981). The selection a research strategy is based on the research questions and research aims, the available time to conduct study, the extent of knowledge, the collection of data, the philosophical underpinning and other available resources. Furthermore, these strategies are not mutually exclusive as well as do not ensure exact answer of the research question. It is necessary to assess their advantages and disadvantages in order to formulate best set of research strategies (Crossan, 2003).

##### **4.4.1 EXPERIMENT**

The underlying purpose of this research strategy is to identify and explore a causal relationship between two or more variables. It identifies a cause- effect relationship, the size of change/ effect and their relative importance. In a classic experiment, two groups are developed on the basis of random selection for testing. Both groups are same in every aspect except the planned intervention which is going to be tested. The group with planned intervention is called experimental group. The other one is called control group (Bryman, 2004).



**Figure 4.3: Process and elements of an experiment (Bryman, 2004)**

#### 4.4.2 SURVEY

The survey strategy is highly suitable and applicable for deductive approach. In the field of business and management, it is most frequently used to answer who, where, what, how and why questions. Surveys offer many advantages to a researcher, but the most important is collection of data from a sample population in numeric form. It allows quantitative analysis to produce generalizable and reliable results. Survey is being done through a well- structured and administered questionnaire. It may contain close-ended or open- ended questions, according to the nature of problem being investigated (Bryman, 2004).

#### 4.4.3 CASE STUDY

Case study is a common research strategy involving an empirical investigation of a particular contemporary phenomenon in a real life context (Robson, 2012). Case study strategy uses multiple sources of evidence in order to empirically investigate a contemporary phenomenon. A particular phenomenon is tested within its real life context. It is totally opposite form the experiment techniques as the research is

undertaken within a non-controlled context (DeBoer, 2014). It stresses the evaluation of real time and practical ideas. If a researcher wants to gain insight of the research processes and context, case study strategy is appropriate. However, it is regarded as one of the challenging strategies in social science research (Yin, 2009). The positive point is that it helps in an in-depth study of the research topic. There are four types of case study strategy i.e. single case (one critical case), multiple case (more than one case, to generalize), holistic case (considering the whole system) and embedded case (study of a number of logical sub- units) (Crossan, 2003).

#### **4.4.4 ACTION RESEARCH**

Action research focuses on the course of action carried to conduct the research. It stresses research in action instead of conducting research about an action. Research is carried out in course of an occupation or activity to make an improvement in the involved approaches and methods. The two main purposes of action research include: the accomplishment of research agenda and accomplishment of needs of research sponsor (Denscombe, 2010). This approach is explicitly related to the development of new theories and concepts.

#### **4.4.5 GROUNDED THEORY**

This is research strategy for inductive approach, better explained as “a theory building approach”. It is a research strategy for prediction and explanation of human behaviour which lead to the development of theory. The role of behaviours is much important in the field of business and management, hence, this strategy helps in exploration of wide

range of behaviours, their effectiveness and contribution in the development of theories (Denscombe, 2010).

#### **4.4.6 ETHNOGRAPHY**

It is another strategy which is used for inductive approach, time consuming and exploratory. It has its origins in anthropology and takes extended time. It explains the social world and describes the research subjects in its social contexts. It demands a responsive and flexible research process because of the continuous development of new patterns by the research during the course of conducting research through ethnographic (Gall, 1996).

#### **4.4.7 ARCHIVAL RESEARCH**

This differs on the basis of data collection processes. It consists of the process of data collection from the official documents and administrative records. The data may be historical or recent, depending on the nature and context of the research (Giacobbi Jr, 2005).

#### **4.4.8 JUSTIFICATION OF THE CHOSEN STRATEGIES: CASE STUDY STRATEGY**

The case study is chosen because the research aims to investigate one issue in depth i.e. BIM applications in construction industry of KSA. Case study approach will help in identification of relationship between research variables in the subtlety and complexity of real world of construction in KSA. The selection of these participants will be done on a concrete criterion (Hirschman, 1986) and interviews will be conducted to discover



deep information and uncovered facts about the BIM applications (Hirschman, 1986). In this study, the case study refers to the KSA and the interviews were conducted from professional working in the KSA construction organisations.

#### **4.5 RESEARCH METHODS**

There are two predominant research methods which are based on the nature of collected data. Quantitative and qualitative are two terms which are used to differentiate data collection processes as well as data analysis procedures. Quantitative method describes the method which depends on numerical data for collection and analysis. It also yields results in numerical values (or in form of graphs, charts, and statistics) (Hussein, 2015). On the other hand, qualitative method predominantly uses techniques which are based on the use of non- numeric data. It also generates non- numeric data as findings or conclusions. Qualitative method focuses on investigation of the nature of problem and development of the deep understanding of the problem. Following three methods are, then, can be used to conduct a research.

**Mono method:** In mono method, a research uses only one technique for data collection and then data analysis is carried out to produce research findings. It may use qualitative or quantitative techniques, solely (Clark, 2005).

**Mixed method:** In a research design, qualitative and quantitative techniques can be used together for data collection. It is, then, called mixed method. There are two types of mixed method i.e. parallel or sequential. In parallel mixed method, both techniques are used at the same time. In sequential mixed method, one technique follows the other. In the mixed- model research, quantitative and qualitative techniques are analysed and

mixed at some stages of the research such as research question development, conclusion or hypotheses development (Riff, 2014).

**Multi-method:** In multi-method, a researcher uses more than one techniques for data collection. This way of conducting a research, in the field of business and management, is increasingly advocated as it brings more accurate and valid understanding of a practical problem. However, all techniques used in a multi method research must fall under either qualitative or quantitative techniques (Taylor, 1984).

In this research, qualitative research method was used adopting mono method. The research relates to the practical business world in the KSA, i.e. construction industry, it is needed to bring forward more generalisable, coherent and reliable research findings, so that the field of construction management in general and BIM in particular could get advantages from this research at a global level and learn lessons.

#### **4.5.1 SEMI- STRUCTURED INTERVIEWS**

There are three main types of interviews in management and social science research studies. These are structured, unstructured and semi-structured interviews. The structured interviews are used for gathering quantitative data in a study and are more used in survey strategy. Unstructured interviews are informal and in-depth interviews. These interviews are used to investigate a chosen topic or area of research and there are no predetermined questions to be asked from the interviewee (Saunders et al., 2009). Semi-structured interviews are classed as non-standardised interviews and are used as a research method for qualitative data collection process. In this type of interviews, the interviewer has a list of predetermined themes or questions to be covered, but the

interviewer may not get a chance to ask all of them (Gray, 2004). Furthermore, the order of the questions can also change based on the emerged issues. Primary data will be collected through semi-structured and structured interviews. The data collected through interviews and was analysed through content analysis.

For this purpose, semi- structured interviews were conducted by selecting a sample of 46 BIM professionals. These professionals were chosen because of their experience in the KSA construction industry and had knowledge of BIM.

**Table 4.1: A break-down of the interviewees**

<b>BIM professional involved</b>	<b>No. of Interviews</b>
Architects	13
Structural engineers	9
Main contractors	16
M&E	8
Total	46

These interviews were conducted through face-to-face interviews. As interviews is the best suited research instrument within inductive approach. Interviews helped in collection of detailed information about the:

- Perceptions, experiences, ideas and concepts which are deeply rooted in the construction industry of KSA. Also, the opinions and perceptions of study participants to get practical information about the BIM.
- Current strategies, tools and technologies will be explored through this method, from the opinions of industry experts.
- Practical information about the applications of BIM, construction management in KSA.
- It will help in extracting expert practitioners' knowledge as well as it helps in covering any research gap, which is the basis of this research.

As this research, has carried out used qualitative methods, this covered the depth of the topic of implementation of BIM and cross verification was done through interviews to bring reliability, validity and generalisability.

#### **4.6 DATA ANALYSIS**

Data analysis involves the separation of research components to produce research findings, which must be valid, reliable and generalisable. Data analysis allows the study of complex things through the identification of their basic elements.

Codes, categories and concepts: Coding and categorising was done as the first step of data analysis in this research. Raw data (collected through interviews) was divided into groups and categories, firstly. These categories of data had some common issues or concepts (to ensure appropriate categorization) (Avolio, 2009). Secondly, these groups were coded for further classification. A software named as NVIVO is used. This software allows the collection and storage of data from the beginning, categorize it and code, afterwards. This software is suitable for coding and categorization of qualitative as well as quantitative data (Bryman, 2004).

Lee and Fielding (1996) found that in qualitative studies the use software for data management is about 40 interviews. In this research 46 interviews were conducted henceforth it was deemed necessary to use NVIVO. Version 11 was available at the University this allowed data to be extracted from professionals in order to create textual data. Using NVIVO 11, the textual data was themed and coded in order to provide reduction to non-relevant data. The themes were based on the perception, driver and challenges of BIM. It helped to highlight keywords and phrases in order to get the most

relevant data. When the data was fully coded it allowed primary data to be deduced. Content analysis was used in this study because this analysis enables the researcher to include large amounts of textual information and systematically identify its properties, e.g. the frequencies of most used keywords in context (Soetanto et al. 2002).

#### **4.7 VALIDITY, RELIABILITY AND GENERALISATION**

**Validity:** The principle of validity is the cornerstone of the scientific research. It constitutes the entire establishment of a research and experimental concept whether the findings meets all of the demands of a scientific research. It ensures the proper application of research methods, strategies and philosophy throughout the conduct of a research. Internal validity confirms that the research design was well- structured and completed all of the scientific research's requirements (Clark, 2005). On the other hand, external validity is related to the examination of research findings and results. It questions the possible outcomes and causal relationships between the research variables. Randomization and use of control groups reduce the external validity problems, however, different approaches need to be followed in order to make a research valid (Creswell, 2002).

**Reliability:** Reliability is concerned with the acceptability of the hypothesis. It is related to the outcomes and demands that a research must find significant results which are inherently repeatable and applicable by other scientists. It reinforces the findings and ensures wider acceptability of research. It is achieved through the use of reliable instruments and methods. To fulfil the requirements of the research and experiments, replication of statistical results is necessary. Reliability can be defined as the ability of an assessment tool to generate consistent and stable results (Denscombe, 2010).

**Generalisation:** Generalisation is the major requirement of any piece of research. It involves drawing of results and inferences in a broader perspective. It is an act of reasoning which is widely- acknowledged in quantitative research. It is taken as a quality standard and impacts the validity and reliability of a research. The research findings of this BIM research in a specific context can be replicated and used as lessons learnt by construction industries in other countries. This can be due to similarities of the challenges and issues being faced by construction practitioners.

#### **4.8 ETHICAL CONSIDERATIONS**

It is mandatory to conduct a research under the due consideration of ethical rules. Access to documents, settings and people (during interviews, case study, etc.) could bring serious ethical problems for a researcher such as confidentiality (Kassarjian, 1977). Therefore, it would make sure to use permissible data on acceptable and negotiable terms from the participant organizations, in this research. It would make sure to seek an informed consent from the participant organizations. Documentary sources will be used to avoid ethical problems. It would help in provision of authentic data without the need of authorization, prior appointment or a contract. Since, the data collection method was interviews, following standards were followed:

- Data will be kept fully confidential.
- Nature of research and use of collected data will be told to the participants.
- It is necessary to seek permission before collection of their responses as well as anonymity will be ensured at that time.
- An easy understanding will be provided to the participants about the research and their level of involvement.

- Personal safety will be ensured as well as anonymity will be maintained.
- Data will only be used for research purpose and will not be exposed, published or sold to other organization to conduct any sort of marketing purpose.

#### **4.9 SUMMARY**

The research aims to explore the implementation of BIM in the KSA. For this purpose, realism and interpretivism are chosen as the research philosophies. Research approach is inductive which is a theory-led approach and is collected through interviews. It helps in extraction of factual information about the current and practical world i.e. construction industry of KSA. Data analysis followed content analysis and was done through Nvivo qualitative data analysis software. Chapter 5, 6 and 7 discuss the findings from the interview data.

## **CHAPTER 5 : THE PERCEPTION FOR IMPLEMENTING BIM IN KSA**

### **5.1 INTRODUCTION**

This chapter 5 discusses the perception of KSA on the concept of BIM, the principle use of BIM and also explores the usage of BIM in the project life cycle from planning and design stage, construction stage and post-construction stage. Furthermore, it also discusses the findings on how organisations succeed if they choose not to use BIM in KSA.

### **5.2 PERCEPTION OF KSA ON THE CONCEPT OF BIM**

In the current study, during face-to-face interviews, in order to capture the general perceptions of KSA construction industry on the concept of BIM, a question was raised, i.e. what does BIM mean to your organisation?

In this study, 46% (21 of the 46) of the interviewees noted that their organisations do not have definite definition for BIM or unaware of BIM tool or because they have little knowledge about the innovative technology. Alongside with the 54% (25 of the 46) interviewees defined BIM as 3D CAD tool. This definition is questioning in the literature. Eastman *et al.* (2011) put forth a conflicting expression that BIM is not solely a software package, but a procedure. As indicated by researchers, BIM might be distinguished as a modelling technology with well-knit techniques to generate, associate and observe building models. Table 5.1 shows some perceptions on the concept of BIM.



**Table 5.1: Typical perceptions of KSA construction organisations on the concept of BIM**

<p>“In its entirety, BIM means the collection, creation and management of information relating to a project for the whole of its life cycle”.</p>
<p>“Creating digital 3D models with project information. This is both to coordinate physically and to communicate within the project between the different disciplines”</p>
<p>“Capturing information of each element in a virtual environment. The organisation has different ideas about BIM, dependant on which sector it relates to”.</p>
<p>“BIM is when 3D geometries in design software are established, then from information on quantities, sizes and numbers and the information is managed where one adds the technical information”</p>
<p>“BIM in the organisation is something that they wish to be market leaders in. However, BIM is not properly understood by those in key roles, the computing power and software is not up to date to meet the demands of BIM and the potential costs of the additional work are not fully understood. Not many members of staff that have the skills or knowledge to undertake, interrogate or review ‘proper’ BIM models confidently and with the level of knowledge that is required. At a personal level, BIM has several different levels which differ in the amount of information that is attached to the ‘model’. BIM means a full 3D model with associated information/database attached to it that itemises/quantifies all the elements used to construct a ‘building’. This database of information can be used for the life of the building for replacement parts etc. Furthermore, the BIM model could be used beneficially should any alterations/extensions be required in the future. Reference</p>

to that model could save time and money. Additionally, BIM could aid in the construction process by combining all design discipline information in to the BIM model which would aid in clash detection and space availability etc”.

“Building Information modelling is effectively a way to take the project online. It is somewhat in its elementary stages, and to harness the full benefit in terms of project management and planning it needs to be used more frequently. It does provide a very useful tool for clash detection, using the federated model”.

“BIM, at its various levels, is now required by many clients as part of their project brief and is mandatory on public funded contracts. As designer’s, BIM requires the recording of design information in a prescribed manner for future use by the client/end user”.

“BIM will provide immediate traceability of the various stages used for design and construction”.

“BIM is the digital representation of the physical and functional characteristics of an asset. It deals with the management of the digital information associated with all the assets on a construction project throughout their whole life cycle. At the end of the day the objective is to enhance collaboration, improve the outputs and reduce project costs”.

The participants interviewed varied in professional roles, therefore what BIM means varied from person to person. It is understood that BIM is a tool to transition from the traditional design/project management methods to bringing the project online and into a virtual 3D visualisation; this enables multi-disciplines to collaborate from shared models. The BIM model can be utilised as a one stop shop for obtaining the required

project information relating to any element of the project. The common theme concerning the interviewee's definitions of BIM was that BIM was commonly perceived as having a lot to do with information management. Moreover, many of the interviewees emphasised that BIM is more than just a model, and that it could be seen as a process of managing information; "Building Information Management" rather than "Building Information Modelling".

Beside the common theme of seeing BIM as something having a lot to do with communication and information management, the interviewees' BIM definitions were expressed in somewhat different ways. Thus, the majority consensus by the interviewees was that there is no unified definition of BIM within the KSA construction industry. Organisations create their own definitions of BIM, customised by the particular way they work with and relate to BIM.

Eastman *et al.* (2011) identify that presenting a uniform definition of BIM is difficult as it provides different functions to various stakeholders in the construction industry. They identify that there is a difference in perception of use of BIM across engineers, construction managers and client. The views observed in the current research correlates with the researcher views in the literature. Most of the interviewees in this study acknowledged that BIM in the KSA construction industry was in its infancy and it is gradually being developed. For instance, one of the interviewees noted that:

"Our particular client has not yet developed much understanding of BIM. The first area they are looking at is improving records management in the operational phase, rather than new asset delivery. As an individual, I do understand the BIM concept and all of the

things that it can achieve, however one of the difficulties of BIM is convincing others with the company that I work in of the benefits working in BIM can achieve”.

Eastman et al. (2011) put forth a conflicting expression that BIM is not solely a software package, but a procedure. As indicated by researchers, BIM might be distinguished as a modelling technology with well-knit techniques to generate, associate and observe building models.

Another interviewee noted that:

“My organisation has been a fore runner in BIM for years and I believe are pushing the boundaries of what we can achieve in BIM at present. I have received a lot of training in Revit and Civils 3D. I have the support of more experienced staff should I have an issue that I can’t Resolve”.

The definition given by most of the respondent indicate their unawareness of BIM concept, because BIM is per be young 3D-CAD tool but rather BIM is a methodology involving the structured creation, partaking, utilisation and re-use of digital data around a building or built quality all through its whole lifecycle, from inception up to the completion, into its operation and management. This comprises the utilisation of harmonised 3D design models enhanced with information which are generated and bring about using a variety of interoperable skills.

The KSA construction industry is heading in the right direction for implementing BIM, however it is lacking BIM knowledge and does not understand BIM as a set of requirements. It is also evident they struggle with software/hardware requirements to enable delivery of 3D models with the integrated information.

Communication is key at all levels to ensure the requirements of BIM, it is only from this process everyone can understand what BIM means. Effective communication allows the required information to be recorded and conveyed in a contractual framework. Hurdles need to be conquered from BIM in relation to communication and ensuring the correct channels are accessible at any given time. Successfully achieving the required communication and BIM knowledge will incorporate the foundations required and establish the fundamentals for BIM implementation in the KSA construction industry.

Awareness of peoples 'background knowledge on BIM is important'. It is often the case that people with CAD skills are then used as BIM operators. The concepts behind the two technologies are different so staff will need to be re-educated in BIM. Legacy ideas are possibly one of the biggest obstacles when adopting BIM. It is important to change the vocabulary and change perception. Also, to operate a BIM system peripheral staff such as IT support will be necessary from time to time.

### **5.3 TO SUCCEED IF ORGANISATIONS CHOOSE NOT TO USE BIM IN THE KSA**

In the current study, during face-to-face interviews, a question was raised, i.e. how likely are KSA construction organisations to succeed if they choose not to use BIM in the KSA? In this study, 70% (32 of the 46) of the interviewees noted that their

organisations would not survive if they choose not to use BIM. However, small projects can succeed without implementing BIM, this is due to the associated costs to offer this service. Choosing not to support BIM will enable smaller engineering companies to survive in the challenging market. This is representative for today's market and weighing the long-term success rate is hard to predict due to the slow progression rate within the industry. Table 5.2 shows typical perception of KSA construction organisations to succeed if they choose not to use BIM.

**Table 5.2: Typical perceptions of KSA construction organisations to succeed if they choose not to use BIM**

<p>“BIM will become a major focus on many KSA construction projects, and an essential part of the design process and beyond. Smaller projects can continue without the need for BIM and this will support smaller engineering organisations delivering cost effectively”.</p>
<p>“Short term, highly likely. Dependant on software development and training, this will become a more cost-effective way to deliver a project. However, the long-term benefits might still be arriving in the distant future, given the current rate of progression”.</p>
<p>“Depends upon what level of BIM is required. Like most things, if you don't keep up with current technology and the demands that clients have, they will be unlikely to succeed. This will require investment in training, IT and BIM”.</p>
<p>“It's early to say if KSA construction companies would succeed embracing the BIM direction, however if the product materialised to reduce consulting and</p>

<p>construction costs, as well as providing added value to clients, it's hard to see how projects utilising BIM would not be able to compete in the market place”.</p>
<p>“BIM is now embedded in the KSA engineering and construction mind-set and would appear to be the way forward. It is therefore unlikely that any construction organisation would be successful without some element of BIM capability”.</p>
<p>“It is a change that will be required by all aspects of the KSA construction industry. So, there won't be an option to choose not to”.</p>
<p>“Very unlikely. BIM perhaps is not for every project or organisation but certainly there will be many competitive disadvantages if not adopted”.</p>

In summary, change from traditional methods can be a formidable thought, the industry requires a platform for an improved construction lifecycle process. Utilising BIM for major projects will be successful, however, acquiring all construction businesses to embrace the implementation will push some companies out of the market place, this will only allow the large companies to survive. A healthy balance of large and small infrastructure companies should be accessible in a fair competitive market.

#### **5.4 THE PRINCIPLE USE OF BIM IN THE KSA ORGANISATION**

In the current study, during face-to-face interviews, in order to capture the principle use of BIM in the KSA construction industry, a question was raised, i.e. What is the principle use of BIM in the KSA organisation? Table 5.3 presents three uses of BIM in the KSA construction organisations as revealed by those interviewed in this study.

**Table 5.3: The key use of BIM in the KSA construction organisations**

<b>Use of BIM in the KSA construction organisations</b>	<b>Most often cited uses</b>	<b>Percentage of interviewees cited (N=46)</b>
Planning and design stage	Existing conditions modelling Cost estimation Phase planning Site analysis Programming Design reviews Code validation LEED validation Engineering analysis Mechanical analysis Lighting analysis Structural analysis Energy analysis Design authoring	91%
Construction stage	3D coordination 3D control and planning Digital fabrication Construction system design Site utilization planning	87%
Post-construction stage	Record model Disaster planning Space management and tracking Asset management Building systems analysis Maintenance scheduling	83%

## **5.5 PLANNING AND DESIGN STAGE**

In this study, overwhelmingly 91% (42 of the 46) of the interviewees noted that their organisations use BIM during planning and design stage of the project. Most often cited uses of BIM during the planning stage include: existing conditions modelling, cost estimation, phase planning, site analysis, programming. Similarly, during designing stage include: design reviews, code validation, LEED validation, other engineering analysis, mechanical analysis, lighting analysis, structural analysis, energy analysis, and design authoring. For instance, one of the interviewees noted that:



“It is mainly use for the preliminary and detailed design phases and in some cases during construction (when working for a contractor). This entails information management, collaboration, efficient workflows, 3D modelling, model coordination, clash detection, asset tagging, health and safety, and on occasions 4D (time) and 5D (cost)”.

As Henry Ford has mentioned in his book, *Today and tomorrow* (Ford, 1926) efficiency is merely the doing of work in the best way you know rather than in the worst way. It is the taking of a trunk up a hill on a truck rather than on ones back. It is the training of the worker and the giving to him of power so that he may earn more and have more and live more comfortably. Ford had the idea that workers would work harder given the right tools at an early stage getting the job done efficiently without having them work harder. The use of BIM at the pre-construction stage gives the client confidence as it minimises surprises during the project, even though BIM is a modelling process, at this stage it is used as a business tool by helping both the client and the contractor in estimating the economic encouragements (Willett, 2008).

Before any construction, studies of energy, lighting and acoustic analysis have to be undertaken, these should be done within the early design stages. With the building information model, energy analysis can be accomplished while efficiency and accuracy are being increased, the BIM allows the parties to make energy efficient decisions and experiment with ideas that can potentially save energy which would improve the quality of the product while saving time (Miller, 2010). For the implementation of BIM, an early start is required from the design and construction stakeholders (Hannon, 2007).

BIM allows the design and construction team to be able to make wise early decisions which will make the pre-construction stage grow. Using the programme to analyse the structure to be built allows them to ask question and receive answers leading to an efficient building. Making decisions before the project begins (Integrated Project Delivery (IPD) approach) is useful as it provides a way in which different stakeholder can share knowledge and business structures. Having the advantage of having a digital view of the proposed project, the design team can be able to keep track to the performance of the design in addition, the building information model also help with the comparison of the designs handed in by different organisations (Smith, 2009). At this moment, clashes are the main source of errors within building construction, BIM being introduced early in the project can detect these hence speeding up the construction process and minimising extra costs for fixing these errors and also reducing legal disputes along the way (Smith, 2009).

Using BIM at the pre-construction stage enables quick access to manipulate the model bringing in different ideas and testing them out (Hardin, 2015). The programme can also be used at the estimating stage which is a very straight forward process as long as the model is built accurately. By using the programme, it is possible to share the company's unit pricing which then allows the design team involved to be able to see the real time gains and losses (Hardin, 2015). Usually in the building and construction business, losing information between the handover phase and the operation of the asset has been an issue resulting in a negative impact on the building operations. By using BIM as a catalyst, a better connection can be made transferring data between the construction and operation stages.

## 5.6 CONSTRUCTION STAGE

In this study, overwhelmingly 87% (40 of the 46) of the interviewees noted that their organisations use BIM during construction stage of the project. Most often cited uses of BIM during the construction stage include: 3D coordination, 3D control and planning, digital fabrication, construction system design, and site utilisation planning. For instance, one of the interviewees noted that:

“BIM is primarily used in the design and asset creation stage. All required information relating to individual entities are recorded and stored within a 3D model. Specifications, method statement and risk assessments can also be stored virtually if the client requires this”.

Another interviewee noted that:

“One of the primary benefits of BIM for a contractor is clash detection, the process of finding where each subcontractors’ disciplines’ models “clash”: incompatibilities and inconsistencies, which would severely impact the construction process.”

The construction phase is where BIM shows a lot of its benefits as it reduces the amount of reworks that have to be done to rectify mistakes. BIM can help with reducing changes and conflict while the construction is going on (Rodriguez, 2014). Modelling tools keep being developed within the programme industry in order to help contractors more with both finding and coordinating the construction process and also in finding ways to get more from BIM by using information exchange to access other systems such as estimating, scheduling and so on (Hardin, 2015).

Hardin (Hardin, 2015) identifies the benefits of BIM during the construction stage, advantages in using BIM are: the programme can be used to analyse physical construction information; manage the amount of clashes; update estimates using the model; improve on-site safety; provide information for as-built and in-field; help with the tracking of material inventory; and prepare the model for the handover phase of the project (when the project is done). Looking at all these advantages, it proves that BIM can be very useful at the construction stage of the project, it can be used by the team as a reference as it is always there in order to help with the development of information. The programme allows necessary changes during the construction stage which can be done with information exchange plans which is what the “I” in BIM stands for. The programme can also be used to check on site conditions without having to go on site.

For instance, clash detection is one of the most important benefits of using the BIM for highway construction. For infrastructure, there are 3 levels of clashes: Level I clash: these are clashes of a drainage pipe or SU’s service or communication ducts with each other or a fixed structure; Level II clash: these are clashes with drainage pipes, SU’s service or communication ducts with each other, a fence installed, signs or lighting post plus clashes with structures; and Level III clash: these are clashes of a drainage pipe or SU’s service or communication ducts with the topography: for example, a drain is above finished road level.

With the use of BIM, clashes can be detected at an early stage, this would mean that extra costs to repair clashes can be avoided resolving conflict. BIM also helps with the products which are manufactured off-site by ensuring that they are a perfect fit making

it easier for the team members on site to be able to fit these elements easily without confusion or delay.

## **5.7 POST-CONSTRUCTION**

In this study, overwhelmingly 83% (38 of the 46) of the interviewees noted that their organisations use BIM during construction stage of the project. Most often cited uses of BIM during the post-construction stage include: record model, disaster planning, space management and tracking, asset management, building systems analysis and maintenance scheduling. For instance, one of the interviewees noted that:

“BIM is primarily used in the asset management stage. As it stands, this is still largely split into several models (2D and 3D) and a H&S file at the end. This is not a particularly user-friendly format, especially for the uninitiated”.

One would think that BIM would only give benefits before and during construction, however it is also useful after construction works are done. Using BIM as a resource for the client can save a lot of time when information is required, however the programme is still a tool that can be valuable as long as the data input is accurate and the user is qualified to use it (Hardin, 2015).

BIM can be a source of information through its 3D demonstration and can show client more about what they want to see depending on how they have refined it throughout its use. Aspects such as the knowledge of the owner, staff skills and the type of facility all have an effect on what the outcome of the project would be and who will be maintain

the product (Hardin, 2015). Post construction, BIM can be used in asset management, scheduling maintenance for the assets, analysis of the building systems, planning for any ruins and also recording the model to help with the maintenance of the building throughout its lifecycle.

The BIM and asset management are both transforming the construction industry and they are both mainly focused on maximising the value of the asset throughout its lifespan, however to attain all of the benefits of BIM with asset management, the collaboration between the different stakeholders must be at maximum level throughout the lifespan of the asset (Ferrovia, 2015).

As mentioned previously, with BIM being used for building, all documentation can be stored within the model. Buildings has a long lifespan and with all this data stored within the model maintaining the asset would become a lot simpler. Using BIM with the asset management of building is a complimentary process as they support each other, the assets help in bringing BIM together whereas BIM assists in introducing new assets into the project and also in operating and managing both new and existing assets. Using information collected from BIM will allow asset managers to register assets and also receive topographic data on the assets and the quantities that were derived. The performance of the assets can also be registered, life expectancy details can be recorded and as infrastructure has a long life span, if maintenance is required a description can be obtained from BIM and in this case maintenance details can also be recorded and stored for future references (ICE, 2015).

## 5.8 SUMMARY

The BIM can be used for a number of effects within the KSA construction industry as it would benefit the project from its prime during the design stage to after the project through asset management (AutoDesk, 2012). BIM is a process that provides a 3D model of the project, unlike AutoCAD which provides 2D drawings, which can be a shared model between the organisations and can be used by architects, engineers, contractors and even the client.

This study revealed that in the KSA construction organisations, BIM is widely used during planning and design stage. Most often cited uses of BIM during the planning stage include: existing conditions modelling, cost estimation, phase planning, site analysis, programming. Similarly, during designing stage include: design reviews, code validation, LEED validation, other engineering analysis, mechanical analysis, lighting analysis, structural analysis, energy analysis, and design authoring. The second most widely BIM used is during construction stage. Most often cited uses of BIM during the construction stage include: 3D coordination, 3D control and planning, digital fabrication, construction system design, and site utilisation planning. The least BIM is used during post-construction stage. Most often cited uses of BIM during the post-construction stage include: record model, disaster planning, space management and tracking, asset management, building systems analysis and maintenance scheduling.

The principle use of BIM in industry is the creation of 3D models for the entire life cycle of the project. Employing enhanced design tools such as clash detection is accomplished throughout the design process maximising the design accuracy. When presenting visualisations, BIM offers the ability to walk around a project in an artificial virtual environment, this enables clients and designers to accurately visualise the

proposed design, this is an important milestone achieved from traditional 2D design methods. BIM is primarily used within the design stage for asset creation, all information relating to individual elements are recorded and if a client requires specifications, method statements, risk assessment etc. these can also be included.

The position of BIM is currently situated within the preliminary and detailed design stage; parametric modelling is a key principle of BIM. Managing the lifecycle aspect can be challenging within the construction industry due to the number of variables that need to be considered. The KSA construction companies that implement BIM in replacement for traditional design methods using BIM only for design specific work will become unsuccessful in realising the true potential and capability of what BIM can deliver.

The BIM has to be implemented in the right way in order for its full benefits to be possible. Training and updating software's are two of the main drawbacks which come with the implementation of BIM. With the KSA construction sector containing older generation engineers, the training process takes longer as the upskilling of the staff would be difficult because the staff would be tempted to use techniques that they have been using for over 20 years.



## **CHAPTER 6 : THE DRIVERS FOR IMPLEMENTING BIM IN THE KSA CONSTRUCTION ORGANISATION**

### **6.1 INTRODUCTION**

This chapter discusses on the key challenges which KSA construction organisations face in implementing BIM. The results discussed in this chapter are based on qualitative data from 46 professionals. The results are based on the perception of the interviewees who participated in this study. The findings are also substantiated with the relevant literature. In this study, eight drivers were revealed. Each of these drivers is discussed in detail. In doing so, this chapter addresses the research question of this study, which is “what are the key drivers for implementing BIM in the KSA construction organisations”.

### **6.2 THE KEY DRIVERS FOR IMPLEMENTING BIM IN THE KSA CONSTRUCTION ORGANISATIONS**

In this study, during face-to-face interviews, interviewees were asked about key drivers for implementing BIM in their organisations. Table 6.1 presents eight drivers for implementing BIM in the KSA construction organisations as revealed by those interviewed in this study. From the data in Table 6.1 it is evident that, client pressure is the most important driver for the KSA construction organisations to implement BIM. This is followed by: competitive pressure, to improve collaboration, Government pressure, to improve health and safety performance, facilitating facilities management activities, to integrate BIM for quantity surveyors, and to improve project management performance. Each of these drivers is discussed in detail below.

**Table 6.1: Drivers for implementing BIM**

<b>Sl. No</b>	<b>Drivers for implementing BIM in the KSA construction organisations</b>	<b>Percentage of interviewees cited (N=46)</b>
1.	Client pressure	91%
2.	Competitive pressure	87%
3.	To improve collaboration	80%
4.	Government pressure	78%
5.	To improve health and safety performance	70%
6.	Facilitating facilities management activities	65%
7.	To integrate BIM for quantity surveying	61%
8.	To improve project management performance	57%

### **6.3 CLIENT PRESSURE**

In this study, 91% (42 of the 46) of the interviewees noted that client pressure is the key drivers for implementing BIM in their organisations. NBS (2015) points out that those businesses who have adopted BIM are willing to communicate its benefits making them clear; these include improved cost efficiencies, client outcomes, coordination, speed of delivery and better data retrieval. For instance, one of the interviewees noted that:

“Clients are increasingly making BIM a requirement, not adopting this we will fall behind competitors. However, implementing BIM is a better way of conducting projects and there are many benefits to be had in terms of effective team cooperation, cost, quality, health and safety, sustainability, etc.”

BIM offers a unique opportunity (RIBA, 2012) and seen as the driver to revolutionise the delivery of construction projects. This is a shift from the traditional inefficient paper-based processes with fragmented project teams to a more integrated, seamless

transfer of data between collaborators who are incentivised to deliver whole life cost (Building, 2014). According to Aranda-Mena et al, (2009) BIM facilitates integration of fragmented practices and act as a catalyst for changing business processes. BIM brings about integration of all stakeholders on a project with improved client relationships; it brings potential for harmony amongst players who in the past would have been adversaries (Azhar et al, 2008).

In summary, the KSA construction industry is competitive and offering BIM provides aspiration to be market leaders between organisations. Some companies are technology orientated and early adopters of implementing BIM, this allows them to stay ahead of the other competitors who are perhaps lagging in the technological ability. This could be related to business goals rather than technological goals. Clients are progressively making BIM a requirement, not adopting this will result in business's falling behind.

#### **6.4 COMPETITIVE PRESSURE**

In this study, 87% (40 of the 46) of the interviewees noted that competitive pressure is the key drivers for implementing BIM in their organisations. Han (2008) surveyed different professionals in the UK, US and other countries, with the purpose of identifying the benefits to the companies who are using BIM technology. The result was that the most significant benefits of implementing BIM are reducing time, cost, improving quality and reducing human resource. In contrast, Eadie (2013) ranked the most influential BIM impacts between 92 different companies. The results showed that the highest impact in BIM implementation is collaboration. For instance, one of the interviewees noted that:

“For us, one of the key benefits for implementing BIM in our organisations was not wanting to be ‘left behind’ the competitors in the market place. The ability to reduce project costs in the later project stages”.

Utilising BIM assists designers and clients to visualise elements or the entirety of a project. 3D models offer a walk through digital visualisation which gives the users an improved decision- making process and can reduce changes later in the project lifecycle. The ability of acquiring new tools such as clash detection will benefit any given project, this enables designers to check drainage infrastructure and other services which may exist allowing engineers to design these out at early stages, compared to traditional methods where this could easily be overlooked and not found until construction stage. This ability alone could achieve a colossal saving on any major project.

In summary, the KSA construction organisations are implementing BIM to make more competitive via intelligent use of data, enables waste to be eliminated from the construction process, and deliver more sustainable construction efficiently and effectively. The use of BIM has enabled more effective design for manufacture and assembly. Greater precision, quality, reduced overall manufacture / assembly time, and safer and cleaner working conditions are benefits of offsite assembly from using BIM.

## **6.5 TO IMPROVE COLLABORATION**

In this study, 80% (37 of the 46) of the interviewees noted that to improve collaboration with stakeholders was the key drivers for implementing BIM in their organisations.

Ma'awuya *et al.* (2013) identify the drivers of BIM adoption in the construction industry as government support through legislature, clients' interest, software availability, collaboration and commitment of professional bodies, and collective procurement process.

“A requirement on projects. Keep up with competition and not be left behind. Models look good, clients have a better understanding of viewing in a 3D environment. Visualisations of constraints and collaboration issues can be easily viewed. In building designs undertaken clash checks are completed to determine if clashes exist and designed out. On one project, not one setting out drawing was produced. All the setting for the building construction was derived from the 3D model”.

Furneaux and Kivvits (2008) mention them as advent of improved IT infrastructure and ability of computer to develop and show 3D models with underlying substantial databases as one of the significant enablers of BIM adoption. Furthermore, Liu *et al.* (2010) further confirm that to improve collaboration with external and internal stakeholders play a vital role for BIM adoption.

GCA (2015) highlighted how they implemented a collaborative and integrated approach to deliver a project using Autodesk BIM platforms. GCA (2015) noted that BIM can help to improve collaboration with different construction stakeholders by identifying opportunities and problems early, clash detections, saving cost and time. BIM offers a better way of producing designs with intelligent objects. Often design may change that

necessitate change in data (Youssef et al. 2016). With BIM, however, the change in design does not lead to change in data, which remain consistent across the changes.

For stakeholders, the most important thing is the data and with BIM, it remains accurate and consistent across all stakeholders (Sampaio and Simes 2015). With BIM, Cross-functional project teams are able to collaborate efficiently. When data remain consistent even when the design changes, the stakeholders, including the teams working on the project retains a clear vision of the project, which facilitates decision-making. Models created using BMI software are intelligent for several reasons. First relationships are kept in the model. Secondly, the information is kept in the model as well. Combining relationship and information with the models means that models know how they relate with each other (Haapasalo, et al, 2015). A model in this sense is a complex database where all the components of the model are kept and can be retrieved on demand. When a designer makes some changes to the model, the software automatically coordinates all the changes in all views that display the elements. Changes therefore do not break the objects, but merely updates the new relationships in the model using the software.

In summary, the reason for using BIM in KSA construction organisations was to improve collaboration between stakeholders, to improve quality, productivity, make better informed decisions, reduce risk and maximise profit; the BIM 3D model provided virtual structure which formed a single point of truth enabling efficient and improved constructability. The collaborative technology of BIM allows harnessing of global technical resources that assist local clients especially for complex projects which require global expertise.

## 6.6 GOVERNMENT PRESSURE

In this study, 78% (36 of the 46) of the interviewees noted that the Government pressure was the key drivers for implementing BIM in their organisations. Most construction companies currently utilise BIM because governments favour its usage. Yoon et al. (2015) agree that most governments have published policies with regard to BIM application in order to ensure safe practice in construction.

For instance, one of the interviewees noted that:

“Clients have been the main drivers, along with government requirements for major projects. We are looking for best examples of how BIM is being used across the business, providing better outcomes, enhancing performance and reducing risk in the built environment. As ever collaboration is at the heart of BIM, so entries must demonstrate this by being submitted on behalf of a number of people that worked together effectively in a model-based environment, both (internally) and with external project participants where applicable”.

Even though Saudi Arabia is also applying sufficient pressure on construction companies encouraging them to use BIM more frequently, it has not yet matched the current. For instance, the government of the United Kingdom has made the BIM of Level 2 mandatory on all projects that are publicly-funded. Yoon et al. (2015) add that even in Australia the Government has adopted similar approach as well. They intend to utilise BIM for all the construction projects within the public sector. Currently there are some national BIM deployments in USA, and Far East. This is a key drive in using BIM

and can apply efficiently to Saudi Arabia. According to Yoon et al. (2015), most governments have placed a policy requirement there are certain projects for which construction companies must demonstrate BIM abilities before they are awarded. Governments are putting this pressure because of BIM's ability to improve H&S performance, cost savings and monitoring, as the potential drivers for BIM adoption in architectural engineering and construction industry (AEC-industry) (Mohseni et al. 2015).

## **6.7 TO IMPROVE HEALTH AND SAFETY PERFORMANCE**

In this study, 70% (32 of the 46) of the interviewees noted that to improve Health and Safety performance was the key drivers for implementing BIM in their organisations. A major part of the collaboration required in the construction sector is related to the incorporation of Health and Safety (H&S) measures in the building models. Traditionally, safety planning was done separately from the other parts of project execution. With this separation, difficulties are created and engineers have substantial problems analysing what, when, and where H&S measures need to be ensured so that accidents are prevented (Zhou, et al., 2015). The inability to coordinate and integrate safety plans, work schedule, 2D drawings and other aspects can create problems in ensuring that safety is maintained in the project. Some of these problems with coordination of plans exist because the construction industry is different from the other sectors (Seokho et al. 2015). The differences are in relation to issues of customisation, on-site assembly, and planning of tasks. It is also a worry for many people that most construction sites are under planned and under resourced. Further, it is important to consider that the collaboration and utilisation of staff is important for the effectiveness and safety of the site. Any tool that can ease tasks is also helpful in reducing wastage



and errors (Al-Jenaibi 2015). This often leads to improved processes and better workflows.

The KSA construction projects still experience high rates of H&S incidents and accidents. The existing cultures in relation to safety and project management fail to effectively plan for safety and health (Baker et al. 2015). These practices, even though applied in projects, fail to apply best practices and provide PPE (Personal Protective Equipment) to guarantee the health and safety of workers (Li et al. 2015). Further, the automation tools and software solutions used in most projects today fail to integrate safety and health in the work process. However, it is believed that BIM technology tools are the best chance for builders to improve their practices related to safety and health.

BIM technology has the potential to be used in safety planning procedures particularly those related to tasks on construction sites. The use of BIM for safety applications in construction has been promoted in academic research circles (Stowe et al., 2014; Eadie, 2013; Yalcinkaya and Arditi, 2013). One study concluded that there is empirical evidence that the use of BIM can enable safety management systems in construction organisations (Wan et al., 2013). Researchers have demonstrated that BIM can be used for automated safety checks based on existing standards of safety (Melzner et al., 2013a; Zhang et al., 2012).

Attempts are being made to formally use BIM in the safety planning phase of a construction project to reduce safety hazards (Melzner et al., 2013b; Zhang et al., 2012). BIM has been used in safety trainings to identify hazards in construction environments (Chen et al., 2013). BIM has been used in the design phase of projects to prevent falls

during the construction phase (Qi et al., 2013). The use of BIM in identifying tie-off points for safety purposes has been demonstrated by Rajendran and Clarke (2011).

## **6.8 FACILITATING FACILITIES MANAGEMENT ACTIVITIES**

In this study, 65% (30 of the 46) of the interviewees noted that to facilitate facilities management activities was the key drivers for implementing BIM in their organisations. Facility owners' can realise the essential benefit on a construction project by using BIM procedures and tools to streamline the delivery of a qualitative and efficient performing building (Eastman et al., 2008; Palos, Kiviniemi and Kuusisto, 2014). BIM creates collaborative processes among project participants, enhancing project delivery process by reducing errors and project variations and leading to project time and cost achievement (Abuelmaatti and Ahmed, 2014).

According to Hammad, Rishi and Yahaya (2012) some of the major constraints facing the construction sector are the multiple natures of projects/construction participants (stakeholders) as well as various stages connected to a construction process. However, disintegration remains an obstacle to smooth and successful information flow among stakeholders which may as a result lead to poor communication and inadequate information handling. The shatter in information flow may ultimately lead to intensification in mistrust and poor relationships between the stakeholders involved in the projects and thus may prompt an internal project conflicts.

Moreover, there is advancement in the areas of information and communication technology which has resulted in innovations aimed at re-engineering construction process from the conceptual phase, through the construction and to operation and

maintenance. BIM is a new approach to incorporate project processes and delivery within which a single comprehensive repository of the facilities data from the inception of the project to operation and maintenance is generated and coordinated collaboratively. It is considered as a new revolutionary success in the construction sector that will improve effective communication and subsequently enhances productivity in construction project delivery (Hammad, Rishi and Yahaya, 2012).

Facilities Management (FM) is regarded as the total management of all services that supports the core businesses of an organisation in a building (Yusuf, Timothy and Charles, 2012). Today's buildings are gradually becoming more complicated and require substantial information to operate and maintain. Facility Managers have to acquire, integrate, edit, and update the diverse facility information, that span from building elements, fabric data, operational costs, procurement/contract methods, space allocation, logistics, maintenance, etc. However, FM professionals faces a lot of challenges resulting in cost and time related productivity, efficiency and effectiveness, losses in the delivering of a successful FM process (Yusuf, Timothy and Charles, 2012). Consequently, Facility Managers are only just beginning to implement BIM for FM, and processes, software and standards are in quite early stages of development (Teicholz, 2013). For BIM to be useful, it must integrate with FM Software (Williams, 2013), such as Computer Aided Facilities Management (CAFM), although there are possible barriers to this.

## **6.9 TO INTEGRATE QUANTITY SURVEYORS (QS)**

In this study, 61% (28 of the 46) of the interviewees noted that to integrate Quantity Surveyors was the key drivers for implementing BIM in their organisations. As BIM is

becoming more widespread and literature has proved that it is taking a commonplace in construction, the relationship with the QS requires looking into in greater depth from existing sources. Stothart (2014) gives an insight as to how BIM currently affects the QS practice and highlights how BIM should be seen more as an opportunity and not a threat as it will change the way QS's work in the future. Stothart also explains how QS practices won't change much with BIM level 2 as each profession currently works from their own model. The researcher knows from previous literature that the UK is currently operating on level 2 until the Government role out their level 3 strategies and implementation. Level 3 will provide a platform where all professionals will work from the same model meaning QS's and MCQS's alike will be able to extract the detailed information required to tender for works more efficiently and manage costs and variations far more easily. However (Eynon, 2016) argues that how quantities, detailed data and schedules can all be obtained from a model environment on BIM, even at Level 2, but the model has to be constructed correctly for this to happen by inputting all the correct data, attributes and classifications into the model.

The take off as an analogue process is laborious and time consuming. Automated take offs, schedules and specifications will become the norm, saving time and vastly improving reliability by reducing human error. They will be used both pre and post-tender by PQS's and MCQS's. Exchange of the digital information with manufacturers, suppliers and subcontractors will speed up and improve the quality and accuracy of the procurement stage (Eynon, 2016).

The rate at which BIM is incorporated into main contracting companies will depend on the benefits it provides and at what cost. The cost for both the software and training will be enough to prevent medium and small sized main contractors from taking on and

utilising BIM, which may mean the end for these practices as they cannot compete with large turnover companies.

#### **6.10 TO IMPROVE PROJECT MANAGEMENT PERFORMANCE**

In this study, 57% (26 of the 46) of the interviewees noted that to improve project management performance was the key drivers for implementing BIM in their organisations. In the KSA construction industry performance is key as it determines deadlines being met and allows construction firms to win work for the future. Achieving a good performance record depends on a variety of measures however planning works is an important factor in attaining top performance. The construction industry is looking to improve the market activity over the next few years and achieving top performance would prove valuable for the industry (Davis, 2015). Improving planning procedures within the industry would boost the industry's performance and by using BIM it would be possible.

The BIM is mostly thought of as a 3D model, however it is much more than that. BIM is a process which aims to improve productivity and reduce costs and can be utilized at any stage of the constructions process from planning to asset management. Most planners would ask how is BIM going to assist with the planning procedure as it is just a 3D model, this is where 4D planning comes in. the BIM process does not just produce a 3D model, but it is capable of much more.

## 6.11 SUMMARY

This chapter discussed the key drivers for implementing BIM in the KSA construction organisations. This study revealed eight key drivers for implementing BIM in the KSA construction organisations. Client pressure is the most important driver for the KSA construction organisations to implement BIM. This is followed by: competitive pressure, to improve collaboration, Government pressure, to improve health and safety performance, facilitating facilities management activities, to integrate BIM for quantity surveyors, and to improve project management performance.

Overall, the study found that the four most important drivers for BIM implementation are “client pressure”, “competitive pressure”, “to improve collaboration”, and “Government pressure”. However, there is a need for providing quantitative evidence of the cost savings and the benefits of BIM for businesses of companies in comparison to traditional methods as a fertile area for future research on BIM in the KSA. Finally, future studies should investigate available methods and approaches for customising an affordable BIM for simple and small-scale projects.

The KSA construction industry is competitive and offering BIM provides aspiration to be market leaders between organisations. Some companies are technology orientated and early adopters of implementing BIM, this allows them to stay ahead of the other competitors who are perhaps lagging in the technological ability. This could be related to business goals rather than technological goals. Clients are progressively making BIM a requirement, not adopting this will result in business's falling behind.

Utilising BIM assists designers and clients to visualise elements or the entirety of a project. 3D models offer a walk through digital visualisation which gives the users an improved decision- making process and can reduce changes later in the project lifecycle. The ability of acquiring new tools such as clash detection will benefit any given project, this enables designers to check building and other services which may exist allowing engineers to design these out at early stages, compared to traditional methods where this could easily be overlooked and not found until construction stage. This ability alone could achieve a colossal saving on any major project.

Every organisation and individuals agree that BIM enables collaboration within projects if implemented correctly. It requires project stakeholders to work together to bring all project data in a single working data rich model. The BIM working platform is recommended to be a common data environment accessible worldwide. The construction industry has identified required BIM activities at each project stage. During the project preparation stage, the client is advised purpose of BIM, benefits and implications as well as level to be utilised, and responsibilities. During the design stage, team members share design data for coordination, analysis and adding specifications. In pre-construction, design is finalised with suppliers and sub-contractors with their respective inputs. During construction data is issued for contract administration and as-built models. After construction data is used for facilities management. BIM usage in hazard identification and safety applications are an indicator of the effectiveness and increasing popularity of BIM in safety applications. This should be considered an essential part of a modern project management system. Among such data, those related to the identification of hazards on construction sites are of great interest to project management decision makers. The application of BIM to improve the safety, facilities management, project management, security and productivity on construction sites has

attracted the attention of the KSA construction industry. Therefore, suppliers of BIM software need to emphasise the different BIM drivers available to ensure organisation select the relevant drivers best suited to their business needs depending on the experience of the organisation that is interested in their software.



## **CHAPTER 7 : THE KEY CHALLENGES FOR IMPLEMENTING BIM IN THE KSA CONSTRUCTION ORGNISATIONS**

### **7.1 INTRODUCTION**

This chapter discusses on the key challenges which KSA construction organisations face in implementing BIM. The results discussed in this chapter are based on qualitative data from 46 professionals. The results are based on the perception of the interviewees who participated in this study. The findings are also substantiated with the relevant literature. In this study, eleven challenges were revealed. Each of these challenges is discussed in detail. In doing so, this chapter addresses the research question, “what key challenges do KSA construction organisations face in implementing BIM”.

### **7.2 THE KEY CHALLENGES KSA CONSTRUCTION ORGANISATIONS FACE IN IMPLEMENTING BIM**

In this study, during face-to-face interviews, interviewees were asked about key challenges their organisations face in implementing BIM. Table 7.1 presents eleven challenges KSA construction organisations face in implementing BIM as revealed by those interviewed in this study.

**Table 7.1: Key challenges for implementing BIM**

<b>Sl. No</b>	<b>Challenges for implementing BIM in the KSA construction organisations</b>	<b>Percentage of interviewees cited (N=46)</b>
1	Organisational culture for change	98%
2	BIM education and training	96%
3	Psychological barriers of BIM implementation	93%
4	The cost of BIM implementation	91%
5	Determining BIM software	85%
6	A collaborative way of working	80%
7	BIM standards and guidelines	76%
8	Meaning of BIM for the KSA construction organisations	70%
9	When to implement BIM	67%
10	Consideration of BIM use and project requirements	65%
11	Implementation methods	61%

From the data in Table 7.1 it is evident that, organizational culture for change is the most important challenge KSA construction organisations face in implementing BIM. This is followed by: BIM education and training, psychological barriers of BIM implementation, the cost of BIM implementation, determining BIM software, a collaborative way of working, BIM standards and guidelines, meaning of BIM for the KSA construction organisations, when to implement BIM, consideration of BIM use and project requirements, and implementation methods. Each of these challenges is discussed in detail below.

### **7.3 ORGANISATIONAL CULTURE FOR CHANGE**

In this study, overwhelmingly 98% (45 of the 46) of the interviewees noted that organisational culture is the key challenge for adoption of BIM in their organisations.

Some of the concerns noted by the interviewees include: leadership issues, unwillingness to share information or knowledge with others, inappropriate training, broken information flow among the parties, inability to exchange and make use of information, unwilling to admit new knowledge, not ready to accept change, and lack of rewards. For instance, one of the interviewees noted that:

“Lack of knowledge of how you apply the principles of BIM in to an project and what level of detail is required is a challenge for the KSA construction organisations. On a major project, the word BIM was included in the employer’s requirements. The employer’s requirements for the whole scheme were essentially written about the public sector that were being constructed as part of the project. After discussion with the employer and representatives they did not require a BIM model for the earthworks project; what they required was a 3D model. These are different things”.

Howson, (2012) indicate that to implement BIM effectively, there needs to be a change in culture and technique to project delivery for BIM implementation. While Black and Gregersen, (2002) contend that to change any organisation, one must first endeavour to change the individual beliefs, attitudes and values (culture) inside the organisation before the organisation in general can benefit. Furthermore, Epstein (2012) unveiled that, upon all the factors that considered in the implementation of new information technology (BIM), culture is the most difficult to segregate, describe and quantify.

Equally Aljaz, (2011) express that the culture influences policymaking, thinking, sensation and the reaction to opportunities and intimidation. It likewise influences how

individuals are selected for a specific responsibility, which influences performances and decision taking. Ashcraft (2008), Gu and London (2010), Sebastian (2010) and Azhar (2011) pointed out the main technical barrier to cultural change in an organisation as interoperability. Further supported by Ashcraft (2008), and Yan and Demian (2008) indicated the human related barriers to change as habitual resistance, inappropriate training and the lack of shared understanding.

In summary, the KSA construction organisations requires dramatic improvements in efficiency, performance, strengthening margins, collaboration and knowledge sharing which generate the need for BIM implementation and to effectively implement BIM it is essential to create positive culture within the construction organisations that widely believed to have an impact on change implementation.

#### **7.4 BIM EDUCATION AND TRAINING**

Overwhelmingly, 96% (44 of the 46) of the interviewees noted that lack of BIM education and skilled personnel was one of the biggest challenges for successful BIM projects implementation in the KSA. Many interviewees noted that their organisations are uneducated in BIM and therefore may not understand the benefits it could bring them. Therefore, many companies make the mistake of sending staff on courses centred on BIM software. Liu et al., (2015) suggest a link between the lack of BIM education available and the lack of skilled professionals required to implement and use BIM effectively; concluding that BIM education is vital in preventing further barriers to BIM implementation. Similarly, Chien, et al (2014), concluded that a 'lack of available skilled personnel' was one of the biggest barriers for successful BIM projects and that it

acted as a catalyst for other barriers. These conclusions both emphasise the importance of strong BIM education. For instance, one of the interviewees noted that:

“The main challenges are almost certainly regarding training requirements for staff. At first it can be a daunting process to familiarise with, which could give people a perceived negative impression before starting. Additionally, there is not a ‘one stop shop’ BIM environment, with different software companies pushing their own products, which can cause confusion between designers and clients. A final point would be computing power. Continuing to develop BIM for larger schemes, the federated model becomes larger and larger, thus requiring a machine that is up to spec”.

In 2013, NATSPEC carried out a study examining the prevalence of BIM education across different countries. The results found that most education was led by software manufacturers, focusing on specific software training and indicating naivety and a lack of education in BIM management and collaborative processes (Rooney, 2014). This highlights a common misconception that BIM is software centred and supports the premise that management and information sharing are the critical areas to consider when undertaking a BIM project (Kokkonen and Alin 2016). Whilst course availability is increasing, especially at degree level, more efforts must be made to incorporate BIM education into the AEC curriculum (Rooney, 2014). If more people have a general understanding of BIM and recognise the benefits it could bring, this may help in pushing the KSA construction industry towards its BIM future.

The lack of BIM education within the industry could also be an underlying cause of psychological barriers to BIM implementation. Many remain resistant to adopting BIM within their work environment. This could merely be a result of limited education, leading to them creating negative personal perceptions and inaccurate assumptions.

Training is essential when implementing BIM. For instance, the training needed for implementing BIM in roadway projects incorporates the use of Civil 3D and Infraworks. Even though they do use Civil 3D, they only implement basic features. For the purpose of implementing BIM, it will be necessary an advance training in Civil 3D. For Infraworks is was more complicated. There are barely some KSA construction organisations implementing BIM in vertical construction. But there is no implementation on infrastructure. Therefore, in KSA there is no training for Infraworks. For that reason, it was found 1.5 hours online course that covers the essential of Infraworks for a total cost of 300 SAR. As it can be perceived this training is not enough for the full understanding of the software as it only last 1.5 hours. Even though there are videos and a training guide provided by AutoCAD, it is important to buy the manual of Infraworks and it is very expensive.

In summary, all staff will need education and training of general BIM, its processes and the management of information. By providing staff with the same education and training it will create unity in the company and give all employees a common understanding. Where appropriate, certain roles will require training in software packages which will add to their BIM knowledge and capabilities.

## **7.5 PSYCHOLOGICAL BARRIERS OF BIM IMPLEMENTATION**

In this study, 93% (43 of the 46) of the interviewees noted that physiological issues of staff are one of the key challenges their organisations facing in implementing BIM projects in KSA. In this study, many interviewees noted that staff show resistance to change, this has mainly been linked to the mature demographic. Scepticism of learning new technologies and changing current work processes are deterring adopters. This issue is also impairing adoption time as people's mentalities must change before BIM can be successfully implemented. Organisation culture and mind-sets are also impeding BIM adoption. Current success without BIM is a detrimental factor to BIM, as KSA construction organisations remain resistant to change without seeing economical proof that it will better their company and bring more profitability.

Smith (2014) states that it is the mentality of staff that must change and be redirected towards a BIM way. He suggests that older and more experienced staff are more resistant to change and may feel overwhelmed by the influx of a younger generation willing to embrace a new age. They may be daunted at the prospect of using new software and technologies as well as the prospect of retraining. Anyone can be trained in new computer technologies; however, experience can only be gained with time and is an invaluable asset (Kokkonen and Alin 2016). Adopting this outlook could change a person's mind-set and encourage them to learn the new skills required to carry out successful BIM projects.

Kokkonen and Alin (2016) also stated a major contributory factor to a slow transition in BIM adoption, is the time taken for people to change their mentality. People's resistance appears to be a critical barrier that must be overcome in order to allow for an

amicable implementation process. If the problem is not eliminated through initial BIM education, a company could consider offering a reward scheme. The commitment of employees throughout the implementation process is critical in order for the company to evolve with the industry.

Reluctance to change and selfish mind-sets of KSA construction organisations is hindering the implementation of BIM. Migilinskas et al., (2013) outline that current project contracts and company organisations focus on the welfare of individuals within a project team, therefore limiting the scope for superior project delivery solutions which could benefit the entire project party. If companies carry out projects in a certain way and profit from this, the risk associated with changing methods, allowing for more collaborative working could be seen as futile. When preparing for BIM implementation, it is important that companies look beyond their own usage and benefits and accept the standardisation BIM will bring across the globe. This will pave the way for better buildings, working life and improvement to the KSA construction industry as a whole.

In summary, it is important to encourage staff and reiterate that new BIM software and processes can be taught and training will be provided; it is experience in the industry that is invaluable. In some cases, construction organisations may wish to use a reward scheme to entice staff and give them something to work towards in places where morale is low. The KSA construction organisations must participate in global BIM adoption and aim to see the long term benefits that BIM can bring not only to them but to the KSA construction industry as a whole.



## 7.6 THE COST OF BIM IMPLEMENTATION

In this study, 91% (42 of the 46) of the interviewees echoed that cost is critical to implementation of BIM in KSA construction organisations. Cost is considered in every element of a business from conceptual decision making through to maintenance and can often be the conclusive factor in many decisions. The implementation of BIM is no different and will have associated costs depending on the outputs required. In a 2015 survey, Liu et al., (2015) proved cost to be the greatest barrier in BIM implementation. This fundamental aspect of BIM adoption is inevitable and costs can include; software, hardware and set-up costs, education and training costs, as well as transitional and behavioural cost associations.

For instance, one of the interviewees noted that:

“Software cost, training cost, additional cost encountered to create a process and procedures is a challenging. Unskilled staff resulted in slower design turn around”.

Ahmad, Demian and Price (2012) explain that there is no correct way of estimating the cost of implementing BIM within a company. No two construction projects are the same, therefore it is impossible for a comparison of cost to be made between a traditional project and a BIM project. However, BIM processes and data may require more time through reviewing accuracy or inputting into the model, which could lead to additional costs in design and management stages (Ghaffarianhoseini et al., 2016).

Through careful planning, programming and extensive research to determine decisions, the cost of the implementation can be managed. Whilst it is difficult to calculate return on investment, investigations into of companies who have successfully implemented and used BIM and seen its benefits could be carried out, gaining knowledge of realistic and relative cost associations.

In summary, estimates must be from initial research to give the company a rough guide of associated costs. If a strategic programme has been created and followed, no additional costs should occur, but there should be a contingency for unforeseen circumstances. Companies that have implemented and used BIM can help to give an estimation of cost and also determine whether, in the long term, it will produce a return on investment.

## **7.7 DETERMINING BIM SOFTWARE**

In this study, 85% (39 of the 46) of the interviewees noted that determining BIM software is one of the challenges for the KSA construction organisations. Sepasgozar, Loosemore and Davis (2016) highlight that each company within the AEC industry will have individual needs, and with the range of products available from specialised vendors it may be hard to choose appropriate products. They also examine the difference between diffusion and dissemination; diffusion relying on word of mouth through social means to influence technology choices and; dissemination involving a managed strategy where the adopters are educated in a product to ensure its suitability (Sepasgozar, Loosemore and Davis, 2016).

“This something which will require a continuous and far reaching effort to deal with the challenges as the BIM discipline crosses so many construction and project management fields. I think we are doing all we can at present to meet the needs of our current work. Perhaps a different way to look at it this is are we looking far enough ahead to predict what we need to be doing in 5, 10, 15 years. As evidenced by the switch from hand drawn design work 20 to 30 years ago to CAD and now the drive towards 3D/4D & 5D design and BIM. What is the next landmark in design evolution going to be? We already have software that enables us to check designs for structural strength etc. I guess we could see the point where we will be able to give some sort of software a brief and within minutes we will have a fully worked out design with all the details needed to construct whatever that design might be. Take it a step further and we might even have a ‘Build It’ button where all the components etc will be shipped to site, the construction and all the other site operations carried out by dedicated construction robots”.

By initially outlining a company’s general project requirements, a suitable business decision can be made on BIM software. Until recently, software licenses were bought out-right and companies would often base their software decision on their competitors choices, often leading to incompatibility with consultants and excess expenditure on further packages. This issue has deterred many from implementing BIM within their company. Nowadays however, many of the leading software vendors such as Autodesk, license their products on a subscription basis. This has taken the pressure off

companies, meaning they no longer have to make a commitment to one piece of software. It allows them to choose a product, implement it and if it does not meet the needs of the company or projects, the process of cancelling that subscription and trialling out another is a favourable option.

However, whilst the pressure has eased in terms of cost and choice, the impact new software has on hardware and training has not. Some software will require new compatible hardware, which can have an impact on cost. Training must also be considered and programmed carefully into the implementation process as this aspect could potentially cost more than the initial software product. Early BIM education and knowledge may aid the training process and software companies may also offer courses alongside their products.

In summary, careful analysis of the industry favourite, competitor's choice, client requirements, compatibility, subscription options, cost and current hardware must be carried out prior to a decision. Where available a company may wish to trial several software before deciding. It is advised that companies make use of the subscription options offered by vendors. This will eliminate the need for a big cost outlay and will offer flexibility to change if necessary. A careful training strategy must be devised, where the appropriate training courses are offered to users. The option of 'employee training' could save time and money. Predominate users will attend specialist training courses and subsequently train their colleagues in it.

## 7.8 A COLLABORATIVE WAY OF WORKING

In this study, 80% (37 of the 46) of the interviewees noted that collaborative way of working is one of the challenges for the KSA construction organisations. Companies within the industry are reluctant to share information with one another (Kokkonen and Alin 2016). This is at the risk of other companies potentially stealing ideas or clients. This has resulted in a very ‘close to the chest’ approach in the AEC industry, with an abundance of issues in information exchange between project consultants. For instance, one of the interviewees noted that:

“Effective collaboration is always one of the main issues, and lack of established procedures. Collaboration, particularly regarding shared models, reasonably instant if the server is located locally but this is not always the case. Large files can take an age to be transferred. Communicating which models are current and which are superseded can cause confusion on large jobs with larger teams working from different offices globally. Hardware restrictions when working on large models”.

This lack of communication has had a detrimental effect on projects and can be costlier for all parties, often leading to uncoordinated design. BIM solutions, such as clash detection and model integration, highlight coordination problems early and an open information environment between project stakeholders, reduces any initial problems dramatically. Liu et al., (2015) signified that enthusiasm and readiness to share data and information amongst project stakeholders is imperative.

Ghaffarianhoseini et al., (2016) explain that data within a BIM model holds much importance, therefore much risk. This could exacerbate collaboration problems, potentially causing legal issues. Smith (2014) outlines that collaborative BIM projects include a vast number of project members, which again, highlights the concern of legal liability. Presently, as each BIM project is unique, there are no standards outlining the legalities and responsibilities of each project participant. To avoid confusion and prevent hostility, Ghaffarianhoseini et al., (2016) suggests the writing of a new contract, outlining BIM responsibilities, limitations and liabilities, giving clarity to all BIM stakeholders. A mutual agreement from the start ensures security and embeds trust between participants; creating a stable foundation to build a project on.

Collaboration between project stakeholders may reduce individual stakeholder gains, focusing on the project gain as a whole (Kokkonen and Alin 2016). Their study also highlighted that when working on a BIM project, stakeholders must create a ‘new company’ with the client uppermost. All stakeholders must turn their loyalties to the client and treat other stakeholders as their colleagues; working together towards one goal (Kokkonen and Alin 2016).

In summary, outlining all BIM outcomes including all roles and responsibilities prior to BIM implementation is essential. The prospect of creating a new contract that outlines all responsibilities, limitations and liabilities will not only offer clarity to all BIM adopters and eliminate future problems, but can aid the implementation process by setting clear objectives and ensuring security between all adopters. The idea of creating an entirely new company where the client is the boss and all stakeholders treat each

other as their colleagues will create unity, allowing for better coordination, better buildings and a better industry.

## **7.9 BIM STANDARDS AND GUIDELINES**

In this study, 76% (35 of the 46) of the interviewees noted that they are conversant with the standards and guidance for BIM management and they believe that BIM is very positive for the KSA construction organisations. However, a worrying statistic is that 24% (11 of the 46) of the interviewees noted that the current BIM standards and guidelines in KSA are not clear and need to relook. For instance, one of the interviewees noted that:

“I guess one of the biggest hurdles we have had is understanding BIM standards and guidelines. In my organisation, a view was taken that we should have a central source for the data that would be used by our various departments around the world and has each country tends to have slightly different standards and guidelines it is important that the content generated is relevant for the country in which it will be used”.

This clearly shows that there is a lack of awareness and education regarding BIM standards and guidelines in the KSA construction organisations. The major issues being an acute lack of expertise in the KSA construction industry regarding the BIM integration, leading to need of much defined industrial standards and protocols. The issue is in alignment with the premise constructed by Forsythe et al. (2015), as they clearly argue that part of the reason adopting BIM technology in Saudi Arabia has

remained low at only twenty percent is lack of expertise and awareness of the BIM standards and protocols.

The complexity and diversity of required BIM standards is further increased due to the integration of the software with diverse stakeholders associated in the construction industry. The software has collectively and interactively to be used by the construction engineers, designers, project managers, quantity surveyors and health and safety experts; which require BIM standards and protocols to integrate information under a single umbrella. Hence, the results reaffirm that the efforts done by KSA government and construction industry oversight mechanism, have not been very successful in providing a satisfying set of standards and rules to be followed (Mohseni et al., 2015).

In summary, the influence of a governing body could be used to devise a national BIM strategy for successful BIM implementation. This could encompass implementation methods, potential problems and how to overcome them and a simple process they could use. There is a call for international BIM standards, which will allow worldwide standardisation and more international projects. Companies could also look to deploy internal BIM standards that all subsidiaries could operate on, ensuring consistency across businesses.

#### **7.10 MEANING OF BIM FOR THE KSA CONSTRUCTION ORGANISATIONS**

In this study, 70% (32 of the 46) of the interviewees noted that meaning of BIM is one of the challenges for the KSA construction organisations and some of the interviewees noted that their colleagues had never heard of term BIM and indication that it was a new term to them. This does not imply that the organisations that they work in do not use



BIM in their construction processes, but rather, the employees might not have been interested in knowing much of what takes place in construction sites. This question reveals that most employees in KSA had some form of information or experience on BIM.

## **7.11 WHEN TO IMPLEMENT BIM**

In this study, 67% (31 of the 46) of the interviewees noted that when to implement BIM is one of the challenges for the KSA construction organisations. When deciding on when to implement, there are two types of companies. First are the ‘go-getters’ or “test pilots”, seizing opportunities despite risks and leading the path to the future. The alternatives are the cautious companies, those who use the “‘wait and see’ approach”. These will wait for others to implement and hope to learn from their mistakes. In some cases, this approach may prove successful. New companies often use the rises and falls of their predecessors to build a strong platform from. However, whilst early adopters build BIM experience, the non-conformers face being left behind in this evolving industry (Prior, 2016). BIM is also being identified as a condition on some projects and if companies do not have BIM capability, they may not even make the consideration of the client.

In summary, careful considerations of BIM outputs and existing capabilities can ensure successful BIM implementation. Adopting BIM is personal to each company and choosing the right time to adopt can improve success, financially and morally. Companies must analyse the market, their clients and competitors and justify if there is a need for BIM implementation. If so, they should carefully plan an implementation strategy. If a company chooses against immediate adoption, they should not distance

themselves and endeavour to take advice from those who have been through the process.

## **7.12 CONSIDERATION OF BIM USE AND PROJECT REQUIREMENTS**

The first decision made by a company acts as a catalyst for all implementation factors. Wrong decisions can be detrimental to the implementation process and all avenues must be explored prior to commencement, as any late changes could be costly and result in failure. When implementing BIM into a company, the first step is to determine its requirements and outcomes. In this study, 65% (30 of the 46) of the interviewees noted that BIM is a complex process and their organisations remain unsure of their roles, usage of BIM and project requirements for the BIM project. Primarily, each organisation must determine their objectives of BIM, project requirements and desired benefits. Migilinskas et al., (2013) concluded, in order for implementation to be successful, prior mapping of work processes and outcomes is crucial, along with the preparation and agreement of interoperability between a project team. This could be outlined within the BIM execution plan and followed throughout the project. The rate of adoption is also important to consider when planning an implementation strategy (Arayici et al., 2011). Pressure from the industry could spark a rushed implementation process and whilst this could eliminate deliberations and hesitancy, it could be a detriment to success and may deter companies entirely. Pressure could provoke short timescales, potentially affecting many factors, such as quality of training and could lead to low self-esteem among employees who may not transition to BIM as well as others. Some companies may choose to set generous timescales, incorporating a well-planned programme of works, allowing for accuracy and giving employees confidence and

experience, prior to working on a BIM project. This method could allow for companies to spread out the costs of the implementation process.

In summary, careful investigations and planning can help to make correct decisions as each decision may affect other elements of the process. Determining BIM outcomes and working backwards will ensure decisions are based around company requirements, hopefully leading to successful implementation. It is suggested that companies carefully programme all implementation works, as implementing over time can increase accuracy, allow staff to gain confidence and experience and help to spread the costs out.

### **7.13 IMPLEMENTATION METHODS**

In this study, 61% (28 of the 46) of the interviewees noted that their organisations are not sure of BIM implementation methods. Coates et al., (2010) discusses two different implementation approaches for implementation: the ‘top-down’ approach, which is primarily client focused, or the ‘bottom-up’ approach, which focuses on staff who will be the users of BIM building on current skillsets. Deciding which approach to take will heavily rely on the company. Arayici et al., (2011) advise using a bottom-up approach, especially in cases where staff are hesitant to change. Whilst client requirements are significant, it is important that BIM adopters and users are comfortable with any transitional changes. They will drive the BIM process, therefore confidence in their capabilities is vital for successful implementation. Likewise, Kokkonen and Alin (2016) outlined two implementation methods for BIM adoption. The first is ‘deconstruction’, starting from scratch and replacing current ideas and processes with new BIM methods. The other method is ‘reconstruction’, taking current ideas and processes and using them as a basis to build on and adapt them to achieve BIM

compliance. Kokkonen and Alin (2016) suggested that neither method should be used exclusively throughout the implementation process, but that each factor should be carefully analysed to determine if any processes could be adapted and if any would benefit from complete restructure.

In summary, it is suggested that companies use a bottom-up approach when devising a BIM strategy. This focuses on the staff, the people that will be using the processes and software that is been implemented. This will encourage staff and build on their capabilities resulting in an amicable workforce and successful BIM methods carried out correctly. It is suggested that a combination of implementation methods are used depending on each task. Where possible, reconstruction is advised, as this provides familiarity to staff and simply adapts current processes. In some instances, it may be better to use deconstruction and start from scratch; this could be a new software platform.

#### **7.14 ASSESSING BIM'S FRAMEWORK**

There are five stages to the BIM framework which could enable an accurate and consistent performance after the implementation of BIM.

- **CAPABILITY STAGES OF BIM**

When a new software process is introduced, it is a necessity for research to be done in order to define the product which is based on the analytical framework that describes BIM in the terms of its maturity level. There are three capability stages of the building information model which show the minimum requirement for implementing BIM “the major milestones that need to be reached by teams or organisations as they implement

BIM technologies and concepts” (Succar, 2009). These three stages separate the processes before BIM has been implemented (pre-BIM) which shows the status of the industry prior the BIM implementation from the processes after the implementation of BIM (post-BIM) (Succar, 2009). The three capability stages of BIM are as follows:

BIM Stage 1: object-based modelling

BIM Stage 2: model-based collaboration

BIM Stage 3: network-based integration

These stages are defined by their minimum requirements.

In order for an organisation to be recognised as stage 1 BIM compatibility, it needs to have had an object-based modelling software which are similar to the following; AutoCAD, Revit, Tecla or Constructor. The same applies to stage 2, the organisation must have or should be at present a part of a multidisciplinary ‘model-based’ collaborative project. For an organisation to be taken as BIM capability stage 3, it has to be using a network based solution, for example like model servers or BIM SaaS, in order to share models that are object based between at least two other parties (Succar, 2009). There are four BIM steps which are required to go through in order to progress along the BIM capability stages, these are:

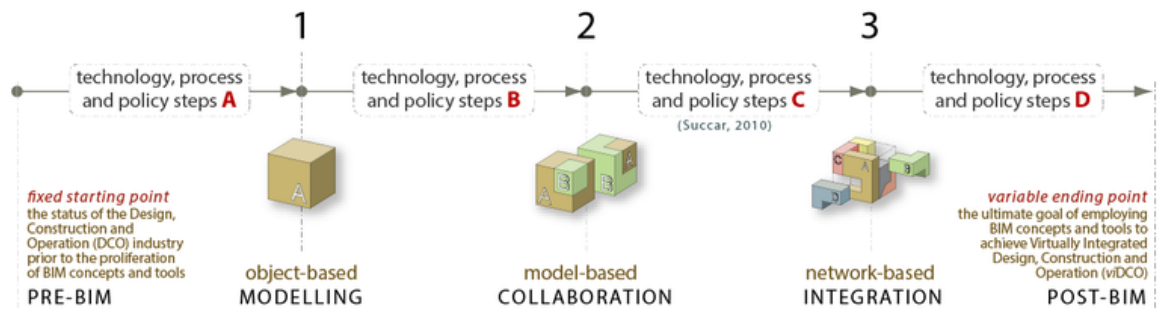
A Steps: from pre-BIM Status leading to BIM Stage 1

B Steps: from BIM Stage 1 leading towards BIM Stage 2

C Steps: from BIM Stage 2 leading towards BIM Stage 3

D Steps: from BIM Stage 3 leading towards post-BIM

Figure 7.1, identifies the BIM steps in accordance to their position on the scale.



**Figure 7.1 Steps leading to the BIM stages**

Source: (Succar, BIM framework, 2013)

- **MATURITY LEVELS OF BIM**

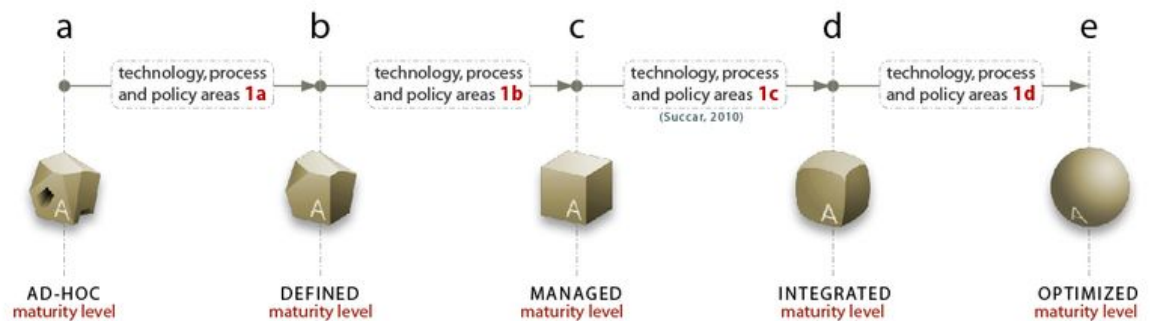
The maturity level of BIM differs from the capability as the maturity level of BIM is based upon quality, repeatability and the degree of superiority with the capability of BIM, whereas the “capability” itself refers to the its minimum ability. BIM’s maturity is provided in levels dependent on the performance and improvement milestones, showing better control and lowering risks and hitting performance targets. The NBIMS test is the National Building Information Modelling Standard test, this test was introduced to measure the level of maturity of the building information model and the processes that were used to create it (Smith, 2009).

The BIM maturity level that was produced was based on BIM’s capability, implementation requirements, performance targets and quality management. There are five levels to the maturity of BIM, where the names were formed by comparing terms that were used by maturity models and the easily understood names were chosen to represent the levels, this decision was made by DCO stakeholders (Succar, 2009). The five maturity levels produced are shown on Table 7.2.

**Table 7.2: Five maturity levels of BIM**

Level	Name of level	Textual rating	Numerical rating
A	Initial/Ad-hoc	Low maturity	0-19%
B	Defined	Medium-Low maturity	20-39%
C	Managed	Medium maturity	40-59%
D	Integrated	Medium-High maturity	60-79%
E	Optimised	High maturity	80-100%

In order to progress from the lower maturity level to the higher maturity level (Maturity levels index in Figure 7.2), organisations should have a better control over having the targets and actual results almost match (acceptable even if little difference) (Succar, 2013), they should also have better predictability which would lead to less risks and a reduction of costs and finally better possibility of reaching their goals and creating new and ambitious ones (Succar, 2013).

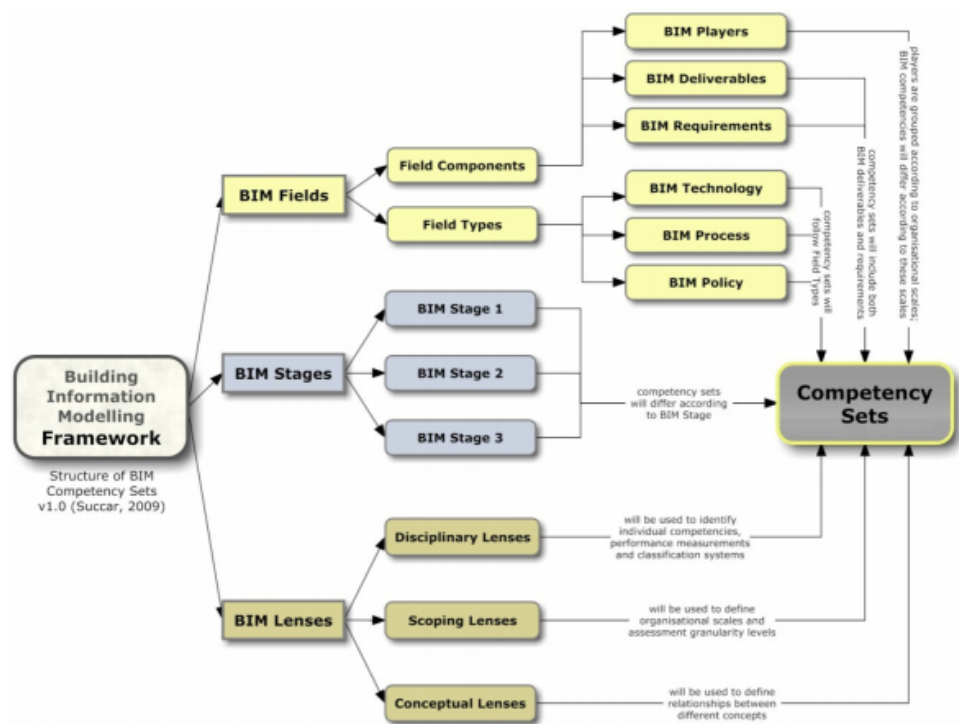


**Figure 7.2 BIM maturity Index (the five distinct maturity levels)**

*Source: (Succar, BIM framework, 2013)*

## ▪ BIM COMPETENCY STEPS

The BIM competency sets are formed of an assembly of different individual abilities for the BIM implementation and assessment. To define the competency of BIM, one could say it is a set of abilities for assessing and implementing BIM's capability and maturity. The competency steps are generated from BIM's framework; Figure 7.3 is the visual of how the competency steps are obtained from the framework.



**Figure 7.3 The structure of BIM competency steps**

Source: (Succar, 2013)

These competencies are an image of the BIM requirements which can be presented in three groups: **Technology sets**- this set relates to the BIM stage 1, which depends on the software, hardware and networks available to change draft-based to object-based workflow; **Processes sets**- this set is dependent on the collaboration and database sharing skills that are required to implement BIM, it relates to stage 2 of BIM; and



**Policy sets-** this set is related to the BIM stage 3, and is dependent on the ability of sharing risks and also contractual agreements. It is to do with the contracts and regulations showing partnership (Succar, 2013). All three sets are linked in some way, as one set finishes the following then commences with the output collected from the previous set.

- **ORGANISATION SCALES OF BIM**

The performance of BIM needs to be able to be diverse within the market, company size and the organisations scale that has been developed, these scales can be used with the assessing efforts modifying them to required details. The organisations scales of BIM include: MACRO which has two parts. Markets- (Markets are defined as the profitable activity where goods and services can be bought and sold) which has three different sectors including Market, Defined Market and Sub-Markets (Succar, 2009). Industries- Industries can be defined as the planned action of the production of goods and services for sale purposes. This sub-scale has four different sectors which are Industry, Discipline, Sector and Speciality (Succar, 2009).

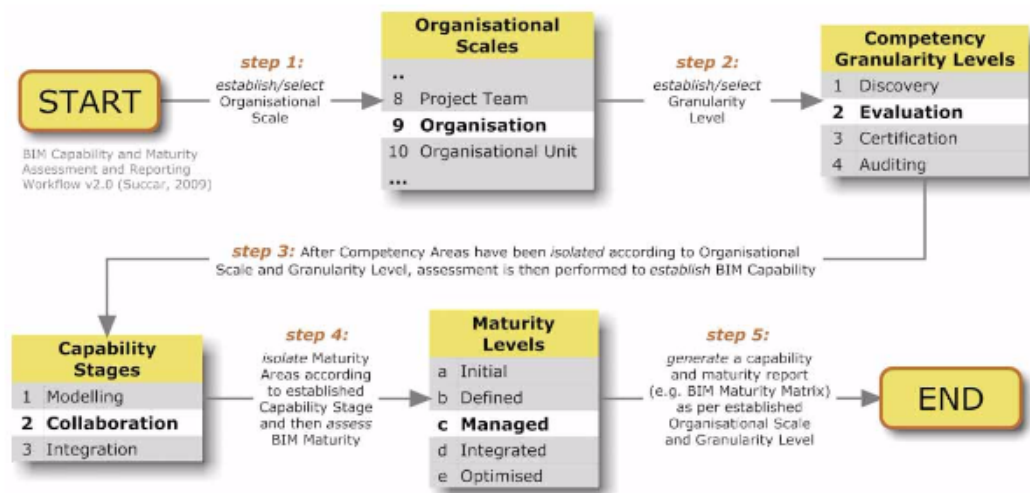
The second organisation scale of BIM is MESO (Project teams) - Project teams can be defined as a planned effort, with a precise goal and hitting these targets in several steps or stages (Succar, 2009). The third and final organisation scale is MICRO (Organisations) - An organisation is a 'social arrangement that aims for goals created by themselves, which has control over the performance, and which has a limit differentiating it from its environment. This scale has four sectors which include: Organisation, Organisational Unit, Organisational Team and Organisational Member (Succar, 2009).

- **BIM GRANULARITY LEVELS**

What are Granularity levels? According to The BIM Dictionary, (AEC, 2015), Granularity levels can be defined as *“The level of detail within a conceptual model, matrix, tool or document”*

Granularity levels were introduced in order to enhance BIM capability and maturity assessments to increase their flexibility. Four levels were developed and organisations can progress from lower levels to the higher levels. These levels are as follows: (i) assessment breadth; (ii) scoring detail; (iii) formality; and (iv) assessor specialization.

Figure 7.4 shows is a summarized image of the BIM framework.



**Figure 7.4: BIM framework**

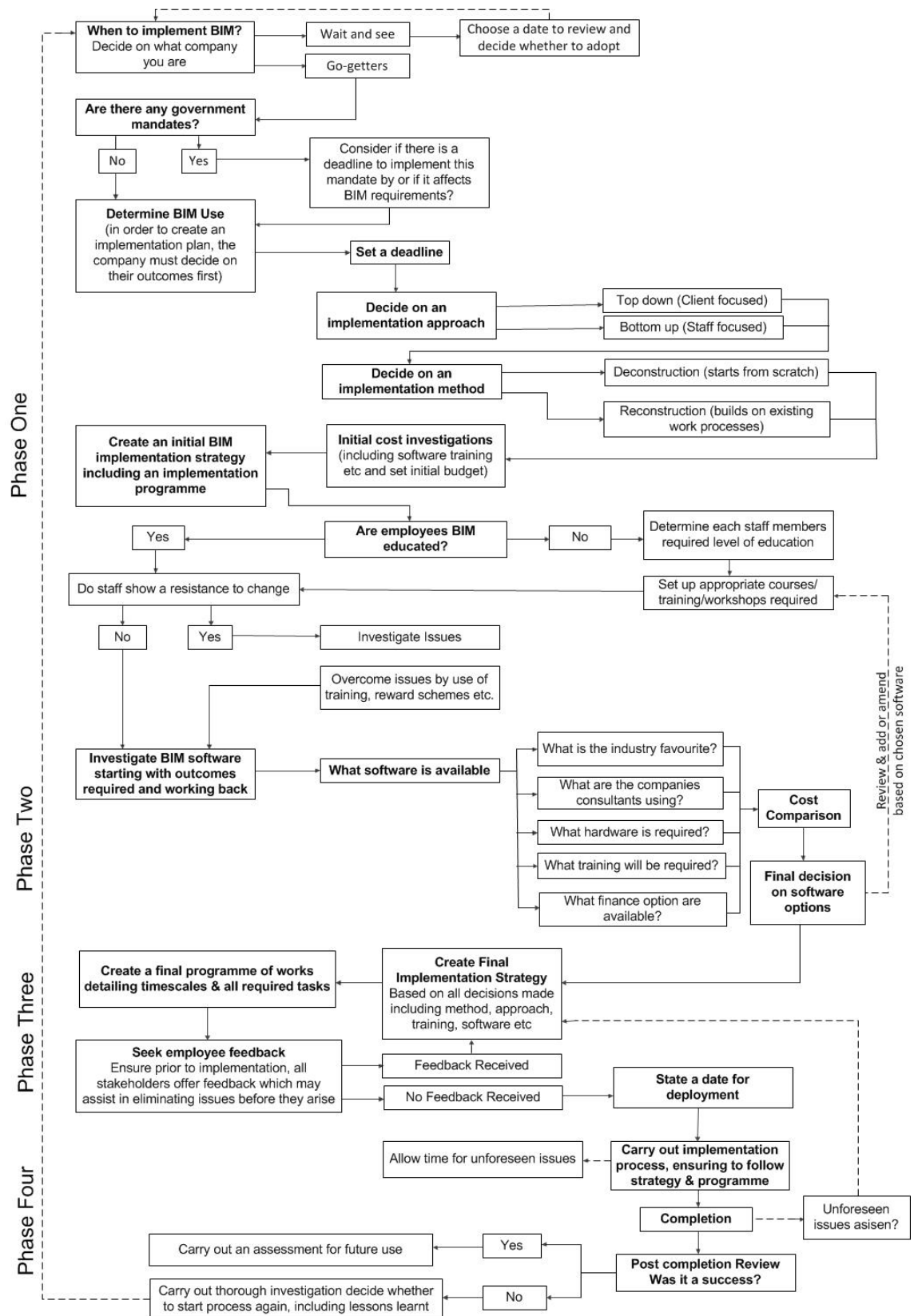
Source: (Succar, 2009)

- **BIM FRAMEWORK AND INFRASTRUCTURE**

Assessing the maturity level of BIM in the software industry is very different to the infrastructure construction industry however the notion of process maturity is the same (Alaghbandrad, 2015). With large infrastructure projects, the use of 3D tools have been limited so far, however if BIM was implemented, as the maturity level gets higher, the

advantages are brought out more as by the time the maturity level is at Managed, the architects get an advantage of using a 3D software in which there is an increasing demand (RIBA, 2012). The models at this stage also assists contractors within the design process ensuring coordination issues are fixed during the design stage rather than the construction stage (RIBA, 2012).

For infrastructure, the higher level it is at while adopting BIM, the better as with an organisation with a BIM capability stage 2 being already a part of a multidisciplinary ‘model-based’ collaborative project would enable the organisation to be able to implement BIM a lot smoother as BIM forms the organisation to be better at collaboration and with that skill already present within the organisation the adoption of the building information model would be most likely successful. Derived from literature review and findings from this study a framework is developed advising a BIM implementation process.



**Figure 7.5: BIM implementation framework for KSA construction organisations**

The framework has four phases. The components in these phases were derived from literature review and the data analysis. Phase one and four was from literature review whereas phase two and three was from data analysis.

Phase one discussed the components: when an organisation is planning to implement BIM therefore must create an initial BIM implementation strategy. When considering the strategy initial cost investigation must be considered which includes software training and budget for setting up. This leads to Phase two where an analysis needs to be based on the software available and affordability to the organisation. Thereafter a implementation strategy needs to be created which is Phase three. In this phase programme of works consisting of detailed timescales and all required task has to be created. It is important that all stakeholders are given the opportunity to provide feedback which may assist in eliminating issues before they arise. This will enable to state a deployment date to ensure the strategy and programme are implemented. Phase four is the post completion review and deal with unforeseen issues that has risen and also include lessons learnt.

## **7.15 SUMMARY**

This chapter discussed the key challenges the KSA construction organisations face in implementing BIM. Eleven challenges the KSA construction organisations face in implementing BIM were listed and discussed. The challenges are: organisational culture for change, BIM education and training, psychological barriers of BIM implementation, the cost of BIM implementation, determining BIM software, a collaborative way of working, BIM standards and guidelines, meaning of BIM for the KSA construction organisations, when to implement BIM, consideration of BIM use and project requirements and implementation methods. It can be concluded that there are a

multitude of challenges hindering BIM implementation in the KSA construction industry. Organisational culture for change is the key challenge for adoption of BIM in the KSA construction organisations. Culture inevitably is difficult to change and manage, as it essentially represents the cumulative beliefs, attitudes and values that individuals within an organisation, group or team possess, which must ultimately be changed if the overall culture is to be changed. Leaders of a change process need to realise that most changes within an organisation will usually cause and expect some change in its existing culture and sub-cultures i.e.: change in certain values, attitudes, assumptions, and behaviours, etc. Therefore, having a better understanding of the effects change has on the sub-cultures of an organisation, group or team, will in turn help leaders of a change process better understand the resistance towards the change itself, and provide a more realistic approach on how to manage it.

Due to the nature of the KSA construction industry, the successful changing of its culture requires clear leadership and commitment from the most senior level of the organisation, group or team throughout a change process, and if required, supported by external consultants. Furthermore, in an attempt to change what people think or do things from an organisation-wide perspective, the change process will be successful, but only if it is strategically led i.e.: when organisations undertake a strategic review early in the change process and, in this way, link culture change to organisational effectiveness. Both managers and employees need to make senior executives more aware of the cultural implications of a strategically led change, and help identify and select the selection, reward, and induction and training programs. However, if general employees are to make an effective contribution to a successful cultural change, they need a better understanding of the organisations overall strategy, vision and commercial

awareness, and how this change will affect their current and traditional “way of doing things”.

Another challenge identified in which a straight forward solution could not be derived from was the psychological barrier. Whilst prior investigations have been carried out in this area, leading to recommendations of what a company could do to ease this issue, nothing to suggest preventing it or resolving it can be deduced. The psychological barrier may also prove the most critical, not only effecting other barriers, but affecting every participant within the implementation process differently. From this research, it appears that careful planning and considerations is essential to address challenges for implementing BIM in the KSA construction organisations. If a company is aware of all possible challenges identified and takes advice about the possible solutions offered whilst following the suggested process, they could in fact implement BIM successfully into their company.

A BIM implementation framework is developed for the benefit of KSA construction organisations. It can aid managers in operationalising a BIM strategy. The developed framework provides a comprehensive approach for BIM implementation. Derived from literature review and findings from this study a framework is developed advising a BIM implementation process.

Overall, the following inferences and implications could be documented:

- Education and training were identified as important parts of BIM implementation due to the process and technological changes it brings in an organisation. This research therefore recommends that BIM education and training programs should be

provided by the academic institutions and other stakeholders in the KSA construction industry to make professional design consultants well familiar with BIM processes to ensure successful take up of the technology. BIM should also be incorporated in the curriculum of all tertiary institutions in KSA taking construction related courses, in order to tackle the dearth of well trained professionals to handle BIM tools in the construction organisations.

- It is recommended that KSA construction stakeholders including the government and professional regulatory bodies should work hand-in-hand in ensuring that the enablers of BIM adoption such as the provision of regulations and industry standards guiding the implementation are provided and strengthened to make the industry ready enough for BIM adoption.
- Consultancy companies in the KSA should further assess their capabilities and address all the issues highlighted in the different categories of willingness to create an enabling environment for them to fully adopt BIM in their practice.
- Through continued efforts in identifying ways to overcome the construction industry's resistance to change, by modifying traditional work habits, by improving current technical limitations, and by encouraging the use of innovative ICT and Internet-based solutions, will undoubtedly help increase the overall knowledge, awareness and skills, of all KSA construction industry stakeholders, in bringing about cultural change. This will result to an important social and technological impact that will integrate the KSA construction industry in a unique, distinctive, and never before experienced way.



## **CHAPTER 8 : CONCLUSIONS AND RECOMMENDATIONS**

### **8.1 INTRODUCTION**

This chapter discusses the aim, objectives and research questions of the study. In doing so, it presents the finding and also provides conclusions and recommendations. The key findings are discussed with respect to the objectives of the study. Prior to that, the research process is discussed.

### **8.2 RESEARCH PROCESS**

The aim of this study is “to investigate how the KSA construction organisations are implementing BIM for competitive advantage”. In order to achieve this aim, the following specific objectives are set:

1. To critically review and document core concepts, uses and applications of BIM in the construction industry within the KSA and internationally.
2. To explore the perception of KSA construction organisations on the concept of BIM.
3. To explore the resilience of the KSA construction organisations in the adoption of BIM.
4. To explore the key use of BIM within the KSA construction organisations.
5. To analyse the specific drivers that have fuelled the need for implementing BIM in the KSA construction organisations.
6. To identify and document key challenges for BIM implementation in the KSA.

7. To develop a framework for the implementation of BIM in the KSA construction project

The qualitative research approach was adopted to collect and analyse data from 46 professionals. Participants in the study included BIM managers. Interviews were audio recorded and then transcribed. As part of the analysis of the interviews, content analysis was employed.

### 8.3 KEY FINDINGS

**Objective 1: To critically review and document core concepts, uses and applications of BIM in the construction industry within the KSA and internationally.**

*Research question 1: What is the operational definition of BIM?*

A critical review was carried out on the core concepts of BIM, its uses and its respective application. For the purpose of this research, BIM is considered as a collaborative process and methodology supported by the use of ICT to manage the essential building design, production and maintenance information through a project life cycle.

**Objective 2: To explore the perception of KSA construction organisations on the concept of BIM.**

*Research question 2: What does BIM mean to your organisation?*

In this study participants interviewed varied in professional roles, therefore what BIM means varied from person to person. The KSA construction industry is heading in the right direction for implementing BIM, however it is lacking BIM knowledge and does

not understand BIM as a set of requirements. It is also evident they struggle with software/hardware requirements to enable delivery of 3D models with the integrated information. Communication is essential at all levels to ensure the requirements of BIM, it is only from this process everyone can understand what BIM means. Effective communication allows the required information to be recorded and conveyed in a contractual framework. Hurdles need to be conquered from BIM in relation to communication and ensuring the correct channels are accessible at any given time. Successfully achieving the required communication and BIM knowledge will incorporate the foundations required and establish the fundamentals for BIM implementation in the KSA construction industry.

It is concluded that, although the importance of BIM is broadly acknowledged within the KSA construction organisations, however there is a significant lack of a common and operationalised understanding on the concept of BIM. Therefore, an industry wide awareness-raising programme on the concept of BIM needs to be developed and deployed. The existing education and training programmes need some reorientation.

**Objective 3: To explore the resilience of the KSA construction organisations in the adoption of BIM**

***Research question 3: How resilient are KSA construction organisations to succeed if they choose not to use BIM in the KSA?***

This study revealed that KSA construction organisations would not survive if they choose not to use BIM. However, small projects can succeed without implementing BIM, this is due to the associated costs to offer this service. Choosing not to support BIM will enable smaller engineering companies to survive in the challenging market.

This is representative for today's market and weighing the long-term success rate is hard to predict due to the slow progression rate within the industry.

It is concluded that, change from traditional methods can be a formidable thought, the industry requires a platform for an improved construction lifecycle process. Utilising BIM for major projects will be successful, however, acquiring all construction businesses to embrace the implementation will push some companies out of the market place, this will only allow the large companies to survive. A healthy balance of large and small infrastructure companies should be accessible in a fair competitive market.

**Objective 4: To explore the key use of BIM within the KSA construction organisations.**

***Research question 4: What is the principle use of BIM in the KSA organisation?***

This study revealed that in the KSA construction organisations, BIM is widely used during planning and design stage. Most often cited uses of BIM during the planning stage include: existing conditions modelling, cost estimation, phase planning, site analysis, programming. Similarly, during designing stage include: design reviews, code validation, LEED validation, other engineering analysis, mechanical analysis, lighting analysis, structural analysis, energy analysis, and design authoring. The second most widely BIM used is during construction stage. Most often cited uses of BIM during the construction stage include: 3D coordination, 3D control and planning, digital fabrication, construction system design, and site utilisation planning. The BIM is least used during post-construction stage. Most often cited uses of BIM during the post-construction stage include: record model, disaster planning, space management and tracking, asset management, building systems analysis and maintenance scheduling.

It is concluded that, the level of implementation of BIM is sporadic. Therefore, BIM has to be implemented in a systematic way in order for its full benefits to be achieved. Training and updating software's are two of the main drawbacks which come with the implementation of BIM. With the KSA construction sector containing older generation engineers, the training process takes longer as the upskilling of the staff would be difficult because the staff would be tempted to use techniques that they have been using for over 20 years.

**Objective 5: To analyse the specific drivers that have fuelled the need for implementing BIM in the KSA construction organisations.**

***Research question 5: What are the key drivers for implementing BIM in the KSA construction organisations?***

This study revealed eight key drivers for implementing BIM in the KSA construction organisations. Client pressure is the most important driver for the KSA construction organisations to implement BIM. This is followed by: competitive pressure, to improve collaboration, Government pressure, to improve health and safety performance, facilitating facilities management activities, to integrate BIM for quantity surveyors, and to improve project management performance. Overall, the study found that the four most important drivers for BIM implementation are “client pressure”, “competitive pressure”, “to improve collaboration”, and “Government pressure”. However, there is a need for providing quantitative evidence of the cost savings and the benefits of BIM for businesses of companies in comparison to traditional methods as a fertile area for future research on BIM in the KSA. Finally, future studies should investigate available methods and approaches for customising an affordable BIM for simple and small-scale projects.

The application of BIM to improve the safety, facilities management, project management, security and productivity on construction sites has attracted the attention of the KSA construction industry. Therefore, suppliers of BIM software need to emphasise the different BIM drivers available to ensure organisation select the relevant drivers best suited to their business needs depending on the experience of the organisation that is interested in their software.

**Objective 6: To identify and document key challenges for BIM implementation in the KSA.**

***Research question 6: What key challenges do KSA construction organisations face in implementing BIM?***

Eleven challenges the KSA construction organisations face in implementing BIM were listed and discussed. The challenges are: organisational culture for change, BIM education and training, psychological barriers of BIM implementation, the cost of BIM implementation, determining BIM software, a collaborative way of working, BIM standards and guidelines, meaning of BIM for the KSA construction organisations, when to implement BIM, consideration of BIM use and project requirements and implementation methods. It can be concluded that there are a multitude of challenges hindering BIM implementation in the KSA construction industry. Organisational culture for change is the key challenge for adoption of BIM in the KSA construction organisations. Culture inevitably is difficult to change and manage, as it essentially represents the cumulative beliefs, attitudes and values that individuals within an organisation, group or team possess, which must ultimately be changed if the overall culture is to be changed. Leaders of a BIM process need to realise that most changes within an organisation will usually cause and expect some change in its existing culture and sub-cultures i.e.: change in certain values, attitudes, assumptions, and behaviours,

etc. Therefore, having a better understanding of the effects change has on the sub-cultures of an organisation, group or team, will in turn help leaders of a change process by incorporating BIM to better understand the resistance towards the change itself, and provide a more realistic approach on how to manage it.

Education and training were identified as important parts of BIM implementation due to the process and technological changes it brings in an organisation. This research therefore recommends that BIM education and training programs should be provided by the academic institutions and other stakeholders in the KSA construction industry to make professional design consultants well familiar with BIM processes to ensure successful take up of the technology. BIM should also be incorporated in the curriculum of all tertiary institutions in KSA taking construction related courses, in order to tackle the dearth of well trained professionals to handle BIM tools in the construction organisations.

**Objective 7: To develop a framework for the implementation of BIM in the KSA construction project**

A BIM implementation framework is developed for the benefit of KSA construction organisations. It can aid managers in operationalising a BIM strategy. The developed framework provides a comprehensive approach for BIM implementation. Derived from literature review and findings from this study a framework is developed advising a BIM implementation process.

It is recommended that KSA construction stakeholders including the government and professional regulatory bodies should work hand-in-hand in ensuring that the enablers of BIM adoption such as the provision of regulations and industry standards guiding the

implementation are provided and strengthened to make the industry ready enough for BIM adoption. Consultancy companies in the KSA should further assess their capabilities and address all the issues highlighted in the different categories of willingness to create an enabling environment for them to fully adopt BIM in their practice.

## **8.4 RECOMMENDATIONS**

### **RECOMMENDATIONS FOR DECISION MAKERS**

- The KSA Government has made public commitments to transform the construction industry through Saudi Vision 2030. The KSA construction organizations are being encouraged to operate efficiently and effectively. Therefore, KSA construction organisations have to embrace BIM practices. The KSA construction industry is heading in the right direction for implementing BIM, however it is lacking BIM knowledge and does not understand BIM as a set of requirements.
- Although the importance of BIM is broadly acknowledged within the KSA construction organisations, however there is a significant lack of a common and operationalised understanding on the concept of BIM. Therefore, the existing education and training programmes need some reorientation. BIM should also be incorporated in the curriculum of all tertiary institutions in KSA taking construction related courses, in order to tackle the dearth of well trained professionals to handle BIM tools in the construction organisations.
- The recent developments in digital technologies present great opportunities for KSA construction organisations wishing to transform themselves into digital business



environment. Therefore, the KSA Government must develop and deploy a policy framework for successful implementation of digital strategies. It is essential that attention is given to capacity building on digital business concepts, strategies, and processes in relation to construction sector. The education and training programmes should be dynamic and adaptable to the increasing changing needs of business, society and people at large.

- The strong leadership, business case for BIM, knowledge building, and creating a culture for change are key ingredients for successful implementation of BIM.
- To address BIM issues and challenges, knowledge is increasingly being accessed and shared across departments and professional boundaries. Cross boundary knowledge transactions also apply to boundaries within organisations, between functional specialism's and between disciplines. Therefore, managing knowledge related to BIM is essential for successful implementation of BIM strategy.
- It is recommended that KSA construction stakeholders including the government and professional regulatory bodies should work hand-in-hand in ensuring that the enablers of BIM adoption such as the provision of regulations and industry standards guiding the implementation are provided and strengthened to make the industry ready enough for BIM adoption.

## **RECOMMENDATIONS FOR KSA CONSTRUCTION SECTOR**

- It is noted that, change from traditional methods can be a formidable thought. The KSA construction industry requires a platform for an improved construction

lifecycle process. Utilising BIM for major projects will be successful, however, acquiring all construction businesses to embrace the implementation will push some companies out of the market place, this will only allow the large companies to survive. A healthy balance of large and small infrastructure companies should be accessible in a fair competitive market.

- The level of implementation of BIM is patchy in the KSA construction industry. The BIM has to be implemented in the right way in order for its full benefits to be possible. Training and updating software's are two of the main drawbacks which come with the implementation of BIM. With the KSA construction sector containing older generation engineers, the training process takes longer as the upskilling of the staff would be difficult because the staff would be tempted to use techniques that they have been using for over 20 years. Therefore, an industry-wide awareness raising programmes on the concept of BIM needs to be implemented.
- There is a need for providing quantitative evidence of the cost savings and the benefits of BIM for businesses of companies in comparison to traditional methods as a fertile area for future research on BIM in the KSA
- The application of BIM to improve the safety, facilities management, project management, security and productivity on construction sites has attracted the attention of the KSA construction industry. Therefore, suppliers of BIM software need to emphasise the different BIM drivers available to ensure organisation select the relevant drivers best suited to their business needs depending on the experience of the organisation that is interested in their software.

- The BIM implementation is in their infancy in the KSA construction industry. There seems to be a significant BIM related knowledge gap that exists across construction organisations. Therefore, sharing best practices related to BIM from other countries and academic research institutes is essential.

## **RECOMMENDATIONS FOR ACADEMICS AND RESEARCHERS**

- For effective implementation of BIM there is an urgent need for KSA construction sector to develop and deploy appropriate BIM related management training programmes. The challenge, therefore, is for construction schools and BIM consultants to bridge the wide gap in the market place. Continuing Professional Development (CPD) programmes and executive training programmes are valuable ways to raise BIM awareness.
- Future studies should investigate available methods and approaches for customising an affordable BIM for simple and small-scale projects.

## **8.5 FUTURE WORK**

This research study has revealed a number of areas for further research and development including the following areas:

- It would be worthwhile to explore the differences between micro enterprises, small and medium-sized enterprises' and large organisations approach to BIM implementation.

- Given that the research reported in this thesis is largely exploratory in nature, the results presented here are only tentative and of limited value for the purpose of generalisation. Therefore, additional research with more elaborate and better articulated designs is therefore called for, to further explore the complex issue of BIM adoption.
- It would be worthwhile to explore the level of adoption of BIM in the developed and developing countries. This should lead to a generation of benchmark data and best practices in addressing global BIM adoption issues.

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## APPENDIX A: PROTOCOL FOR SEMI-STRUCTURED INTERVIEWS

### Interview questions

Date	
Time of interview	
Name of organisation	
Organisation's sector	

Name of Interviewee	.....
Position of Interviewee	.....
Organisation's total employee size	.....
	<ul style="list-style-type: none"> <li>Please kindly tell me a little about what your current job role is in the project/organisation?</li> </ul>
	<ul style="list-style-type: none"> <li>Given your role in this organisation, please explain what does "BIM" mean to you and your organisation?</li> </ul>
	<ul style="list-style-type: none"> <li>What were the main issues and challenges encountered when working with members of your team/disciplines within the infrastructure projects?</li> </ul>
	<ul style="list-style-type: none"> <li>Can you describe the key drivers that have fuelled the need for implementing BIM initiatives in your project/organisation?</li> <li>In your opinion, how likely are construction organisations to succeed if they choose not to use BIM?</li> </ul>
<i>The next few questions will focus on key challenges your organisation face in implementing BIM strategies.</i>	
	<ul style="list-style-type: none"> <li>From the job role and responsibilities that you perform in this organisation, please, describe the principle use of BIM in your project/organisation?</li> <li>Do you think BIM is only successful for large complex projects?</li> <li>When using BIM on your project, how challenging was the transition from the traditional project management methods?</li> <li>Have you encountered any challenges because of the use of BIM within your project?</li> </ul>
<i>The discussions have been very interesting. The next question will focus on the impact of BIM initiatives on organisational competitiveness.</i>	
	<ul style="list-style-type: none"> <li>Given your job roles and responsibility, kindly explain how the efforts of BIM initiatives have contributed to your project's/organisation's competitiveness?</li> <li>Have you benefited from cost reduction after the initial investment required for implementation?</li> <li>Have you benefited from early programme delivery?</li> </ul>

Thank you for your views on the above questions. I would also like to thank you for the time you have dedicated to this research. If you are interested to know the outcome of this research, it would be my pleasure to share it with you.

## CONSENT FORM

### Implementation of BIM in the KSA construction organisations

#### Consent Statement

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the “Information Sheet”, a copy of which I have retained.
- I understand that I can withdraw from the project at any time and do not have to give a reason for withdrawing.
- I consent to participate in an interview with the researcher.
- I understand that my personal information will remain confidential to the researcher.
- I understand that my organization will not be identified either directly or indirectly.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

Contact Address:

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Phone Number: \_\_\_\_\_

Fax Number: \_\_\_\_\_

Email Address: \_\_\_\_\_